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# CONTINUOUS PIGGERY WASTEWATER TREATMENT WITH ANAEROBIC BAFFLED REACTOR (ABR) BY BIO-ACTIVATOR EFFECTIVE MICROORGANISMS (EM4)

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## ABSTRACT

**Aim:** The purpose of this study was to determine the efficiency and characteristics of pig wastewater treatment. This was to be achieved using ABR with the addition of effective microorganism4 (EM4) as a bio-activator during the startup process (R1) and without EM4 (R2). **Methodology and Results:** Piggery wastewater is poured into ABR with 12 hours HRT (hydraulic retention time), though it is reduced to 6 hours after the concentration is stable. The COD removal efficiency at 12 hours HRT was 60% (R1) and 51% (R2). However, the results did not change significantly, since the 6 hours HRT COD efficiency was 57.8% (R1) and 51.3% (R2). The biomass growth rate at R1 is faster than R2 with Food to Microorganism Ratio (F/M) 0.4-0.89 (R1) and 0.68-1.38 (R2) while the yield of methane gas formation was 0.25-0.28 L-$CH_4$/g-COD. **Conclusion, significance, and impact study:** COD effluent is the total organic material present in the piggery wastewater effluent, which is discharged into water bodies without meeting the set quality standards. This damages the quality of water bodies. The wastewater treatment needs to be prioritized to meet quality standards of COD effluent. Also, the addition of EM4 to the activated sludge reactor improves the COD removal efficiency and biomass growth, though advanced treatment is still needed for piggery wastewater.

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## KEYWORDS

- ABR
- Biomass growth
- COD
- HRT
- Piggery wastewater

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## 1. INTRODUCTION

The piggery industry is one of business that can be found in various regions in Indonesia. These industries consist of farms, slaughter house and culinary. Each region in Indonesia has a typical food with pork as the main ingredient. Variations culinary in pork make piggery restaurants become one of the potentials tourism sector in Indonesia (Suarna and Suryani, 2015). However, the development in piggery industry has problem. The by-product of piggery industry activities is piggery wastewater that is difficult to treat because of its high organic matter (oil and fat) (Suryawan *et al.,* 2019a). Piggery wastewater is characterized by high organic nutrient concentrations, such as $NH_3$-N, and $PO_4$-P (Meng *et al.,* 2017). Water pollution and eutrophication occur when piggery wastewater is disposed improperly. The remaining of piggery wastewater treatment that is disposed directly to the environment has bad effect to the quality of environment (Zainuddina *et al.,* 2019) and human health. In order to prevent pollution and ensure the existence of farmers, the piggery wastewater treatment need to be redesigned.

Anaerobic baffled reactor (ABR) is the most often method that is applied in piggery wastewater treatment (Chen *et al.,* 2016; Pereira *et al.,* 2013). ABR is a modification of anaerobic bio filter. ABR process includes the growth of micro bacterial into attached media to increase the efficiency of wastewater treatment biologically. ABR has a baffle or bulkhead, a hybrid reactor with sediment that is used to absorb organic matters. The baffle can drain wastewater upward through the mud layer reactor. ABR is a reactor that is easy to operate, inexpensive, and does not require electrical energy (Hassan *et al.,* 2013). Even today the use of ABR in piggery wastewater can be combined with a microbial fuel cell to obtain electrical energy (Ye *et al.,* 2014).

Conventional activated sludge often use to treat wastewater with low C/N ratio. Therefore, this method requires high cost and simple maintenance to operate (Anshah and Suryawan, 2018; Suryawan *et al.,* 2019c). This conventional method also requires continuous treatment to eliminate organic nutrients. Piggery wastewater has a low C/N ratio so it is difficult to remove nitrogen. Denitrification bacteria will be hampered due to inadequate carbon sources when the C/N ratio is lower than 3.4 (Hu *et al.,* 2014).

Limited number of dissolved oxygen (DO) can provide optimum conditions for anammox bacteria to live. These bacteria can eliminate organic matters like $NH_3$-N and total N (TN) optimally (Meng *et al.,* 2018). Nitrification and denitrification of autotrophic bacteria will be inhibited when

organic carbon sources are present in wastewater due to the competition with heterotrophic bacteria (Ni *et al.,* 2012). In dark fermentation phase, the yield and conversion rate of the substrate by bacteria depends on the type of reactor and parameters, such as the organic loading rate (OLR) (Arimi *et al.,* 2015). OLR value refers to the amount of organic matter expressed in chemical oxygen demand (COD) that is divided by volume reactor in anaerobic decomposition process for certain period (Mariakakis *et al.,* 2011). The obstacle that occurs in conventional reactors for anaerobic condition is washout, which is carried out by microbial population along with the discharge of wastewater.

The critical parameter in continuous reactor are OLR in wastewater and the hydraulic retention time (HRT). The increasing OLR can increase the production of methane's volume. If HRT was shortened, the system can be failed due to the rapid changing of VFA (volatile fatty acids) or microbial washing of anaerobic digestion (Xie *et al.,* 2012). According to Sasse (2003), the design criteria for HRT in the ABR reactor are 6-14 hours. The use of anaerobic processes is very helpful to treat and convert organic matter in piggery wastewater into methane gas. The aimed of this study was to determine the degradation process of chemical oxygen demand (COD) by consortium bacteria and compare the process with and without EM4 as bio activator.

There are five main groups of microorganism contained in EM4 are photosynthetic bacteria, *Lactobacillus* sp., *Streptomyces* sp., yeast, *Actinomycetes* (Rasmito *et al.,* 2019). The combination of ABR with startup of EM4 and wetland method capable to reduce concentration of COD 58.7% (Mardianto *et al.,* 2014; Tazkiaturrizki, 2016). Another anaerobic reactor used bio filter with addition of EM4 reducing BOD 45.01% and $NH_3$ 37.96% (Natsir *et al.,* 2019).

## 2. RESEARCH METHODOLOGY

### 2.1 Piggery wastewater characteristic

The characteristic of piggery wastewater need to be analyzed because its characteristics have to be qualified for next treatment. The ratio of COD (chemical oxygen demand) to Total Kjeldahl Nitrogen (TKN) or C/N is 1.55. This value is effective to remove Nitrogen in ABR wastewater treatment (Chen *et al.,* 2018).

## 2.2 Microorganisms

Effective Microorganisms 4 (EM4) is a mixed culture in a yellowish-brown liquid medium, smelling acidic and consisting of microorganisms that benefit to soil fertility (Rasmito *et al.,* 2019). The types of microorganisms in EM4 include *Lactobacillus* sp., Yeast, *Actinomycetes* and *Streptomyces*. The addition of EM4 can degrade organic matters. EM4 also stimulates the development of other beneficial microorganisms such as nitrogen-fixing bacteria and phosphate solvents. Seeding and acclimatization processes were carried out before ABR treatment. Bacteria grown in the reactor must have been attached to the baffle inside the ABR. Acclimatization is carried out by providing organic loads of wastewater from low concentrations to full wastewater.

**Table 1** Piggery wastewater characteristics

| Parameter | Influent Quality | | Quality Standard | Unit |
|---|---|---|---|---|
| $BOD_5$ | 4,853 | ±251 | 100 | mg/L |
| COD | 9,480 | ±289 | 200 | mg/L |
| $NH_3$-N | 34 | ±0,88 | 25 | mg/L |
| TKN | 3,134 | ±125 | | mg/L |
| TP | 578 | ±76 | | mg/L |
| pH | 7.7 - 8.1 | | 6-9 | - |
| BOD/COD | 0.51 | | | - |
| C/N | 1.55 | | | - |

- : no unit

## 2.3 Reactor and analysis

The reactor used in the treatment process is an ABR reactor with a volume of 25 L and HRT of 12 hours and 6 hours (Figure 1). 12-hour HRT was carried out at the beginning of treatment and HRT was reduced to 6 hours after the COD parameter was stable. The reactor in this study was divided into startup of adding EM4 (R1) and without addition EM4 (R2).

The piggery wastewater was analyzed for the following elements: $BOD_5$, COD, volatile suspended solids (VSS), total nitrogen balance (TKN), as defined in the Standard Method reference. COD measurements were carried out using the open reflux process. Biogas formation is measured based on the volume calculation in a volumetric flask. Gas meter collection chamber to measure the volume of produced methane gas. The gas meter (Biogas 5,000 analyzer) was filled with 2.5% solution of NaOH in order to dissolve and separate carbon dioxide in the biogas (Figure 1). The Volatile Suspended Solid (VSS) is a part of mixed liquor volatile suspended solids

(MLVSS) consists mostly of microorganisms. To measurement the MLVSS fraction used filtrate the activated sludge through 0.45 micro filter and furnace at 550 °C.

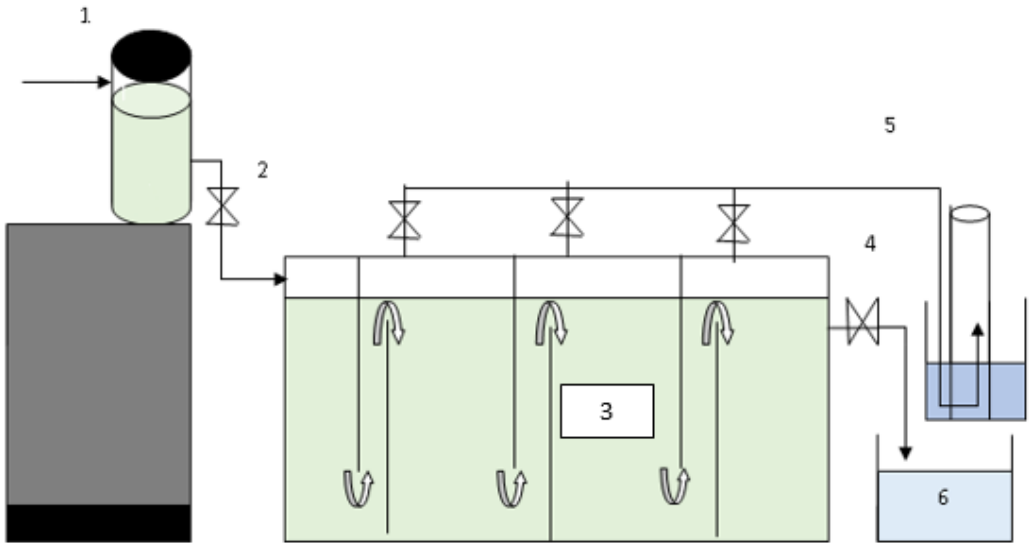


**Figure 1** ABR reactor design (1) roof storage tank (2) valve (3) ABR (4) water effluent channel and sampling port (5) biogas trap with 2.5% solution of NaOH (6) effluent storage tank

## 3. RESULTS AND DISCUSSION

### 3.1 COD removal

COD influent concentrations for reactors R1 and R2 were 4,853 ± 251 mg/L and 9,480 ± 289 mg/L, respectively, while the average effluent of reactors R1 was 5,011.5 ± 1,123 mg/L and 5,423.3 ± 1,341 mg/L for R2 (Figure 1). The efficiency of R1 on HRT 12 hours for COD removal were quite good which is around 60%. Whereas R2 showed efficiency not much different from R2 which is 51.4%. Increased levels of MLVSS and decreased levels of influent pollutants were indicated greater reduction in COD levels (Figure 2). This is due to the high interaction between microorganisms in sludge and wastewater. Figure 3 shows that addition of EM4 as start-up microorganism can increase MVLSS levels in ABR. This MLVSS level is very important in determining the F/M ratio to optimize ABR. The average value of the F/M ratio in this study is 0.61±0.16 d-1 (R1) and 0.9±0.26 d-1 (R2).

Another studies show similar result for efficiency of COD removal by ABR method in piggery

wastewater, 60% (Ye *et al.,* 2014). The result that is conducted by Chen *et al.,* (2016) showed efficiency of COD removal by 40% (at 13- 22 days), and it is similar with the average efficiency in this study. The C/N ratio in the study showed a value of 0.56 ± 0.09, with the contributing bacteria were 92.70% for anammox and 7.30% for denitrification.

Jijai *et al.,* (2008) conducted a study using continuous up flow anaerobic sludge blanket (UASB) reactor to treat cannery seafood. Variations at 6 hours HRT obtained COD removal efficiency less than 50%. Krishna *et al.,* (2009) designed an ABR with HRT 8 hours and 10 hours, and influent concentrations of COD 502 ±6.19 mg/L and 501 ±7.19 mg/L. That reactor had removal COD 90.0 ±1.05% and 90.7 ±0.4% which is greater than this study (Krishna *et al.,* 2009). The quality of effluent can be improved by carrying out advanced wastewater treatment. The BOD/COD value in this study was less than 0.2. based on that value, the recommended treatment for increasing BOD/COD values is ozone treatment (Suryawan *et al.,* 2018; Suryawan *et al.,* 2019b; Kim *et al.,* 2014) and followed by aerobic activated sludge to increase the quality of wastewater effluent (Cheng & Fallowfield, 2017; Nasr *et al.,* 2019).

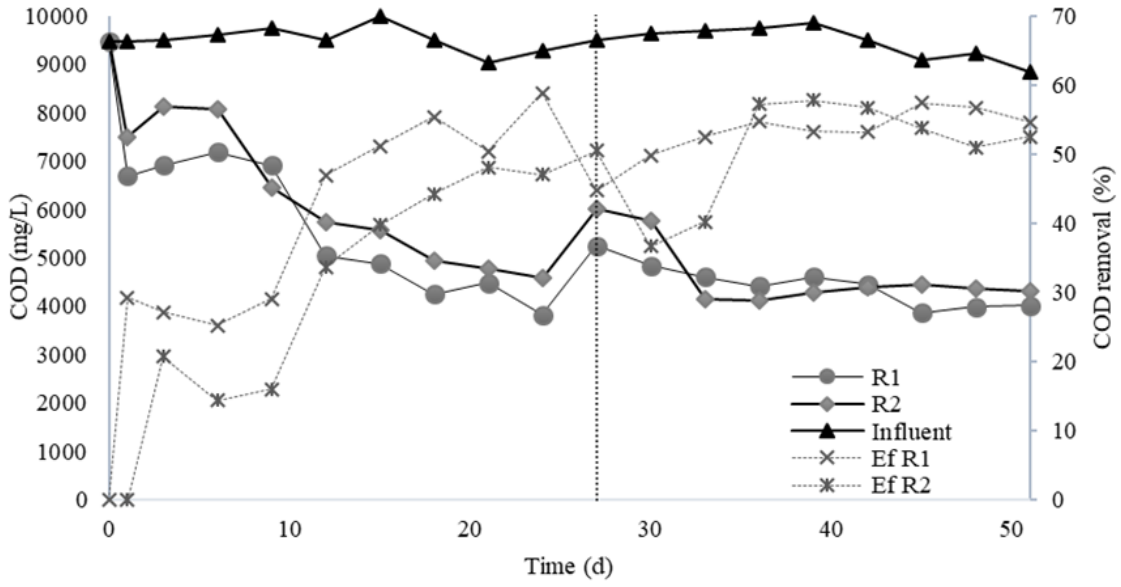


**Figure 2** The results of COD concentration in ABR are 51 detention days (0-24 days with HRT 12 hours and 24-51 days with HRT 6 hours)

## 3.2 Biomass Production

Increased levels of MLVSS and decreased levels of influent pollutants were indicated greater reduction in COD levels (Figure 2). This is due to the high interaction between microorganisms in sludge and wastewater. Figure 3 shows that addition of EM4 as start-up microorganism can increase MVLSS levels in ABR. This MLVSS level is very important in determining the F/M ratio to optimize ABR. The average value of the F/M ratio in this study is 0.61±0.16 d-1 (R1) and 0.9±0.26 d-1 (R2).

The interaction of COD and MLVSS causing microorganisms to reduce the level of COD in pollutants. Similar observations were found in other studies (Bassuney *et al.,* 2013). The start-up with EM4 will distinguish the amount of biomass in the ABR. The biomass growth rate on day 1 are 0.0135 (R1) and 0.127 (R2). This result was similar with other studies, which state that the stability of anaerobic sludge can be increased by prolonging contact's time of sludge and wastewater. This condition made the bacterial growth rate increase to remove pollutants.

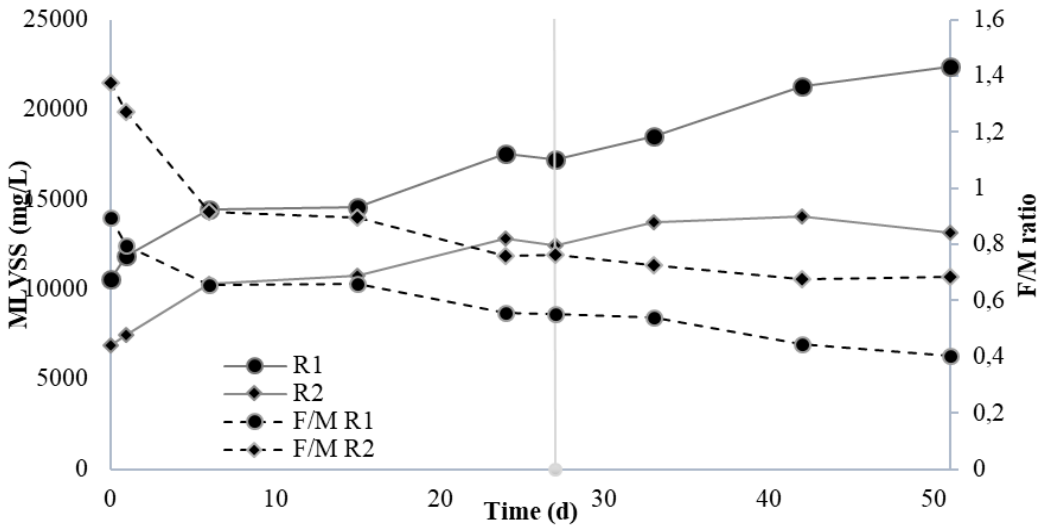


**Figure 3** The measurement results of the MLVSS value in the reactor R1 and R2 along with the calculation of the F/M ratio of the reactor R1 and R2

## 3.3 Biogas Production

Methane gas had been formed on day 6 by HRT 12 hour treatment. The amount of substrate content in the wastewater must be maintained so that the bacteria continue to develop well. The amount of fat contained in the wastewater will affect the remodeling activity of carbohydrate

and protein waste. The production of biogas began to be detected on day 19 of 0.08 L-$CH_4$/g-COD removed. This value will increase along with the ABR reactor operational time. Observation of yield value at the end of the experiment showed a value of 0.25 (R1) and 0.28 (R2) L-CH4/g-COD removed.

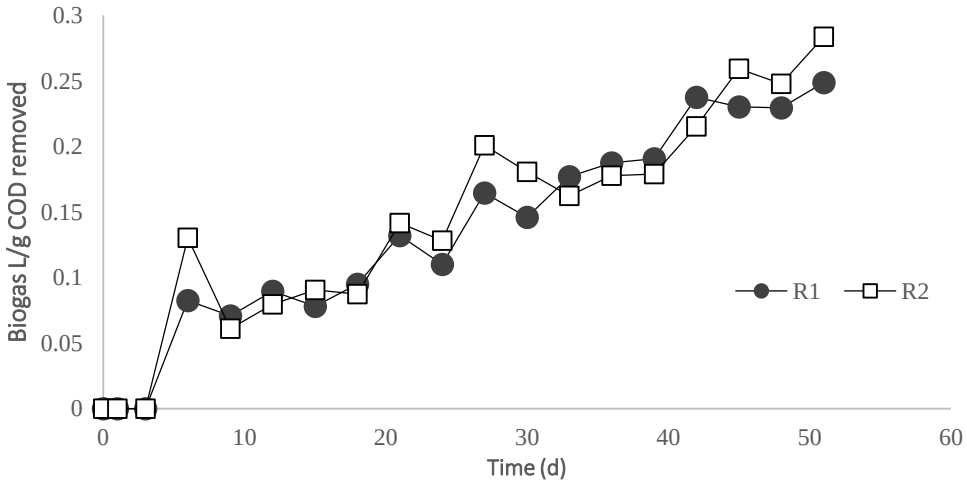


**Figure 4** The measurement methane yield value of the reactor R1 and R2

By increasing OLR (organic loading rate), the production of methane is increased gradually because organic material were available and converted to biomass. The results of methane production/COD removed have similar results with other ABR studies with value 0.25 L-$CH_4$/g-COD (Malakahmad, 2014). Lower results are generated by other studies using UASB with value 0.115 L- $CH_4$/g-COD (Intanooa *et al.,* 2016). The increase in OLR causes decrease in methane content and this resulted in an increasing rate of acid genesis and non-proportional growth of methanogens, which consumes CO2 as substrate to produce methane.

## 3.4 Biogas Production

The initial pH of R1 was 7.82 and R2 was 7.76 and continuously decreased at day 6 (Figure 5). The culture pH was acid and then returned to 7.46±0.08 (R1) and 7.53 ±0.09 from 9-51 days. pH was one of the most important parameters for the degradation of organic matter with ABR which could affect the activity of acid genic and methanogenic microorganisms (Liu *et al.,* 2008). It happened because organic acids were accumulated rapidly and produced lower biogas (Yang *et al.,* 2015).

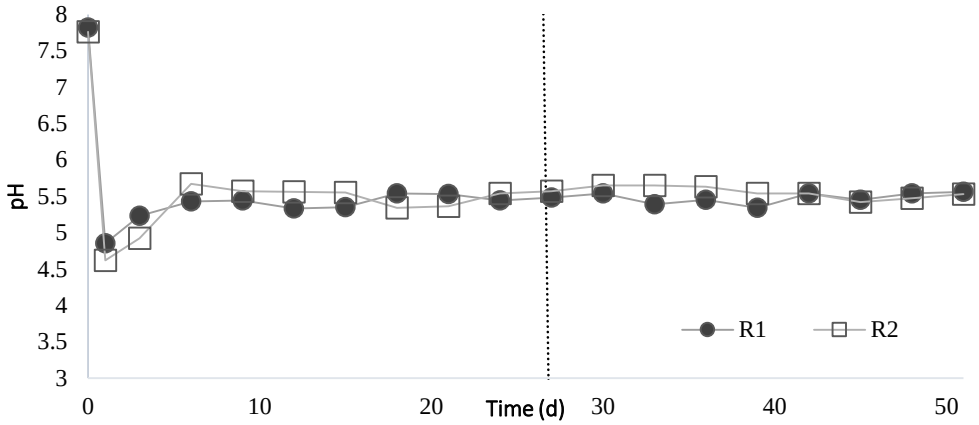


**Figure 5** The measurement pH value of the reactor R1 and R2

## 4. CONCLUSION

The average of COD efficiency in this study were 47.2% (R1) and 42.8% (R2) with total methane production on ABR was 0.24-0.26 L-$CH_4$/g-COD removed. The COD efficiency in ABR treatment was still low, so that advanced wastewater treatment (ozone treatment Ozone treatment and followed by aerobic activated sludge) is needed to improve effluent's quality for water reuse (consumption; feed production; drinking; servicing; processing).

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