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PALM FROND BIOCHAR FOR SLUDGE GRANULATION IN AEROBIC GRANULAR SLUDGE SYSTEM

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Abstract

This work investigated the role of biochar derived from palm frond addition in an aerobic granular sludge system to improve the granulation of sludge. The effect of biochar dosage was analysed based on the granules size and chemical oxygen demand (COD) removal performance. At the same time, the system performances including sludge volume index (SVI_{30}), mixed liquor suspended solid (MLSS) and mixed liquor volatile suspended solid (MLVSS) for 50 days were studied. Three identical of 2 L reactors which operated based on sequencing batch reactors (SBR) system were used in this study named R1, R2 and R3. Difference dosage of biochar was added into R2 and R3 which is 4g and 8g, respectively while, R1 as a control system with no biochar added. The existence of biochar improved the granulation process as aerobic granule size of 0.95- 1.49 mm with clear boundary was observed at 14 days of system operation. The biochar supplemented in the reactors act as a core for microorganism to accumulate and enhanced the granulation of sludge. After the granulation, R3 shows a good settling characteristic compared to R1 and R2, with an SVI of 50 mL/g SS at the end of system operation. The reactors performed steadily with COD removal efficiencies of 85%, 90% and 96% in R1, R2 and R3, respectively at initial COD concentration of 500 mg/L and 24 h of SBR cycle. The dosage of biochar had a positive impact on granulation and reactor performances even at the short duration of system operation.

Keywords--Aerobic granular sludge, palm frond biochar, SBR, dosage, wastewater treatment

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INTRODUCTION

Aerobic granular sludge has become a promising wastewater treatment technology due to its unique features of excellent settleability, high biomass retention and high resistance against a wide range of organic loading and environmental conditions. In addition, theaerobic granules exhibited a compact microbial structure, good settling capability and high biomass retention, which classified them as a versatile wastewater treatment system. Dense and compact aerobic granular sludge structure contributes to a good settling ability which allows high biomass retention in reactor for the degradation process of organic matter which it is the main factors for the granulation field received attention by many researchers in the wastewater treatment.Aerobic granulation has been mainly successful developed in sequencing batch reactors(SBR)which had been widely extended the usage of lab scale SBRs operated with a simple operation into a higher leveloperation which equipped with a control and automation system to optimize the SBR performances (Lemaire*et al.*, 2008). Therefore, numerous studies had been done focused on understanding ofmechanisms (Li *et al*., 2020), factors and optimizing the reactor operating conditions in promoting aerobic granulation (de Sousa Rollemberg*et al.,* 2020).

Recently, researchershave focused on improvement study in the accelerating granulation process of aerobic granular sludge in SBR as this technology is limited by the drawback of the long start-up period of reactor. Liang *et al.,* (2017) demonstrated a novel granulation strategy by introducing magnetic nanoparticles in an aerobic granular system which successfully improved the time of theaggregation process. Meanwhile, the used of rice husk biocharin aerobic granular sludge system reported by Zhang *et al*., (2017) and Ghani*et al.,* (2019), which had successfully developed a compact structure of aerobic granules at 60 days of cultivation in pyridine wastewater. The biochars act as a nucleus that enhancing the aerobic granulation process by facilitated the growth of microorganisms due to its coarse and irregular surface and characteristic adsorption property (Li *et al.,* 2011). Thenucleus or cores,which located in the centre of aerobic granules is important in reinforcing the granular structure (Zhang *et al*., 2017). Thus, the existence of the supported material in the aerobic granulation system is significant inorder to improve the granulation time and maintain the granule stability.

Although the application of biochar as a nucleus of aerobic granular sludge, especially biochar derived from feedstock such as rice husk, rice bran and walnut shell which was studied by Ming *et al.,* (2020) had been investigated, they have different properties in physical and chemical which driven unique influence on theformation and performances of aerobic granules (Kambo and Dutta, 2015). Therefore, an effect of palm frond biochar in aerobic granular sludge system was explored in this study.

METHODOLOGY

Preparation of synthetic wastewater

The synthetic wastewater contained phenol (0.2 g/mL), NH_4Cl (0.20 g/mL), $MgSO_4.7H_2O$ (0.13 g/mL), K_2HPO_4 (1.65 g/mL), KH_2PO_4 (1.35 g/mL) and for an optimal microbial growth, 10mL of micronutrients was added in each reactor. Micronutrient consists of H_3BO_3 (0.05 g/mL), $ZnCl_2$ (0.05 g/mL), $CuCl_2$ (0.03 g/mL), $MnSO_4.H_2O$ (0.05 g/mL), $(NH_4)Mo_7O_{24}.4H_2O$(0.05 g/mL), $AlCl_3$ (0.05 g/mL), $CoCl_2.6H_2O$ (0.05 g/mL) and $NiCl_2$(0.05 g/mL).

The pH of the wastewater pH was adjusted to 7 by adding $NaHCO_3$.

Preparation of biochar

Palm fronds were collected from Sime Darby Sdn. Bhd Plantation Pengkalan Bukit Estate Muar, Johor. The leaves were removed and washed with tap water to remove any dust particles and cut into smaller size. Palm fronds were left to dry under the sun for 3 days to reduce moisture content. Then, the palm fronds were dried in an oven at 105ºC at 24 h to avoid the growth of fungus. After drying oven, palm fronds were ground and sieved through the sieves of 150µm size by using Sieve Shaker EFL 300. Dried palm fronds were stored in airtight container for further use. The palm frond was carbonizedin a PROTERM furnace at 550 °C for 1 h to obtain biochar properties.

Experimental and reactor set-up

Three identical high and slender reactors (14 cm in diameter and 49 cm in height) named R1, R2 and R3with working volume of 2 L which operated based on the SBR system were used in this study.The schematic drawing of the reactor shown in Fig. 1.4.0 and 8.0 g of biochar prepared as above was added into R2 and R3, respectively, while R1 is a control reactor without biochar but operated under identical operation. The reactors were operating at 24 h cycle, which consist of four stages, including 30 min of feeding, 1350 min of aeration, 30 min of sludge settling and 30 min of effluent withdraw. The operation of three reactors werelasting for 50 days. The influent with COD concentration of 500 mg/L was introduced from an influent tank and the effluent was discharged through the outlet ports of the reactor with 50% of volume exchange ratio. An air pump was used to supplying fine air bubbles and located at the bottom of the reactor. The reactors operated at room temperature (27 ± 1 °C).

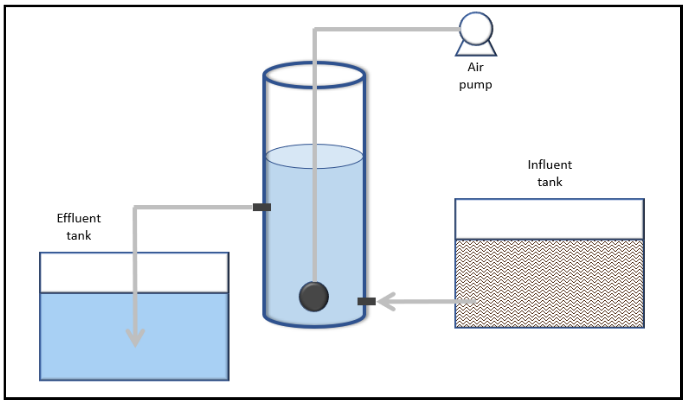


Figure 1. Schematic drawing of reactor operated based on SBR system.

Analytical methods

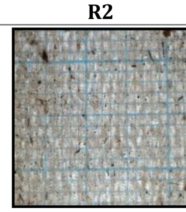
Mixed liquor suspended solid (MLSS), mixed liquor volatile suspended solid (MLVSS), sludge volume index (SVI_{30}) and chemical oxygen demand (COD) removal were conducted according to the APHA standard methods (APHA, 2005). The pH and DO of the reactors were monitored using a portable multiparameter (HQ440d-HACH). The morphology of granules was examined using a digital camera. A vernier calliper was used to measure the size of the granules at every 1^{st}, 14^{th}, 30^{th} and 50^{th} day reactor operation.

RESULTS AND DISCUSSION

Aerobic granules development

The measurement of granulation growth and aging process is based on the granule size. Table 1 shown the increment of granules sizes in R1, R2 and R3 from day 1 to 50.From day 1 to 14, no granules were observed on R1, meanwhile 0.95 mm of maximum granule size was observed in R2 and 1.49 mm of granule size was observed in R3 during 14 days of operation. After 30 days, R1 was successfully developed 1.16 mm of maximum size of granule and at the same time, R2 and R3 shown a significant granules size increments up to 2.54 mm and 3.21 mm, respectively.All the observed granules had a clear boundary, brown colour and uneven surface properties which similar to Yulianto*et al.*(2019)that had developed granules with 3.25mm size.By day 50, the largest granules with 3.69 mm, 4.16 mm and 6.51 mm diameter was developed in R1, R2 and R3, respectively which had irregular shape. The granules size improvement in each reactor shown the significant improvement of aerobic granules in the presence of biochar. Since R1 was operated without any existence of biochar, the granulation in R1 shown the slowest process compared in R2 and R3. Thus, the existence of biochar is enhancing the granulation process as an attachment core for the biomass growth, which driven to a rapid and stable sludge granulation.

Table 1. Photograph of seed sludge at day 1 and aerobic granules and size at day 14, 30 and 50 of operationin R1, R2 and R3.

Day of operation	R1	R2	R3
1	 Seed sludge	 Seed sludge	 Seed sludge

14	 No granule observed	 0.95 mm	 1.49 mm
30	 1.16 mm	 2.54 mm	 3.21 mm
50	 3.69 mm	 4.16 mm	 6.51 mm

Biomass concentration and sludge settling

The settling properties and biomass concentration in term of MLSS and MLVSS in the aerobic granulation system is reflected to the developed granules characteristic. Fig. 2 shows the MLSS profiles of R1, R2 and R3 for during the reactor operation. During the reactor start up, each reactor recorded 4200, 3800 and 6000 mg/L of MLSS, respectively. After 15 days of operation, the MLSS of R2 and R3 were slightly increased to 5000 and 8300 mg/L while MLSS in R1 decrease to 4967 mg/L due to the washout of excess sludge during discharge due to poor settling ability of the seed sludge in the reactor. The MLSS was continuing to increase throughout the operation process as the biomass already acclimatized with the wastewater as explained by Harun*et al.,* (2014). At the end of the operation, thehighest concentration of MLSS achieved in R1, R2 was 6500 mg/L and 124500 mg/L in R3.

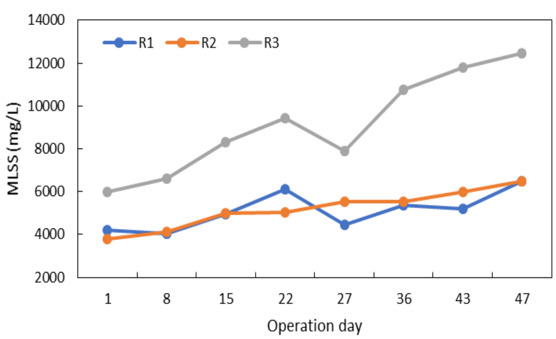


Figure 2. MLSS profile in R1, R2 and R3

Fig.3 shows the MLVSS in R1, R2 and R3 during the SBR operation. At 8 days of operation, MLVSS concentration gradually keeps increasing after the start-up from 3800 mg/L to 5567 mg/L in R1, 4550 mg/L to 5400 mg/L in R2 and 5650 mg/L to 11550 mg/L in R3. However, R2 experienced a major washout on day 15 which resulted the MLVSS concentration in R2 decreased to 4250 mg/L from 4550mg/L. According to Moustafa (2014), biomass were found difficult to maintain within the reactor because of the biomass was not given sufficient time to aggregate during an early stage and a large portion of the sludge was washed out during the discharge phase. Starting from day 22 onwards, MLVSS concentration in R1, R2 and R3 kept increasing steadily. After the aerobic granules start to form in day 30, the MLVSS value of R3achieved the highest compared to R1 and R2. This is because the amount of dosage supplied in R3 contributes to the increased of MLVSS as provided by Zhang *et al.,* (2017).

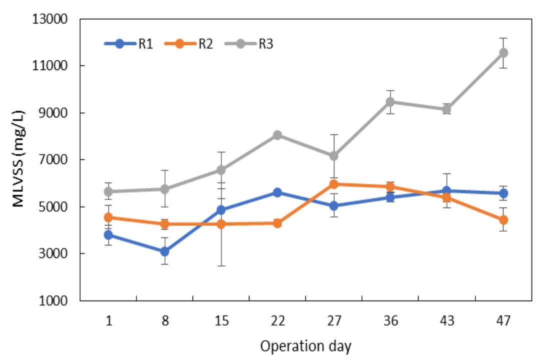


Figure 3. MLVSS profile in R1, R2 and R3

The good performance of aerobic granular sludge in separation between sludge and water was evaluated in term of sludge volume index (SVI) (Ma *et. al.,* 2012). Fig. 4 shows the SVI profile of R1, R2 and R3during the operation. At the early stage, high value of SVI of R1, R2 and R3 were recorded as 127.4, 131.7 and 89.9 ml/g, respectively, on day 8, which shown the sludge had a poor settling property. After 30 days of operation, the value of SVI was gradually decreased to 88.3 mL/g in R1, 88.1 ml/g in R2 and 67.9 ml/g in R3 as the granules were starting to develop in the reactors. The SVI in each reactorwascontinued decreasing during the operation, but R1 has shown a slightly slower decreasing of SVI compared to other reactors. At the end of the operation, R3 had the lowest SVI value which is 50 mL/g compared to R1 and R2 and demonstrating an excellent settling properties as the biochar in the reactor functioning as the core for the biomass attached and accumulated densely. According to Zhang *et al.,* (2017) and Tay *et al.,* (2001), the SVI value between

30-40 mg/L represented an excellent settling properties of mature aerobic granules in a system. Thus, the result showed that the settling ability of aerobic granular sludge was improved together with the granulation process with the addition of biochar.

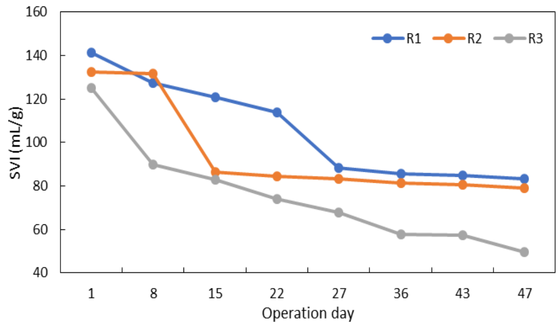


Figure 4. SVI profile in R1, R2 and R3

COD removal performances

The COD influent supply for each reactor was kept at 450-500 mg/L. Fig. 5 shows the comparison of COD removal efficiency for R1, R2 and R3. Initially the COD removal efficiencies of the R1, R2 and R3 were low 30%, 31% and 34%, respectively. This is because the lack of stability in aerobic granules. During the operation, the COD removal in all reactors shown a positive performance as the COD ineffluent is reducing. As the granules started to develop, the removal efficiencies in R2 (60.5%) and R3 (75%) at 29 days of operation is slightly higher than R1 (47.5%). This proved the supplied biochar in R2 and R3 has not just enhanced the granulation growth, but also improved the removal performance of COD. At the end of the operation, the effluent in R1 is 73 mg/L, which recorded 84.7% of COD removal efficiency. Meanwhile 44 mg/L of effluent COD was observed in R2, which contributed the COD removal efficiency of 90.8% and 95.8% removal achieved in R3 with 20 mg/L of COD effluent.This result is comparable to COD removal of 94% reported by Khan *et al.,* (2010) with no biochar is supplemented into the reactor.

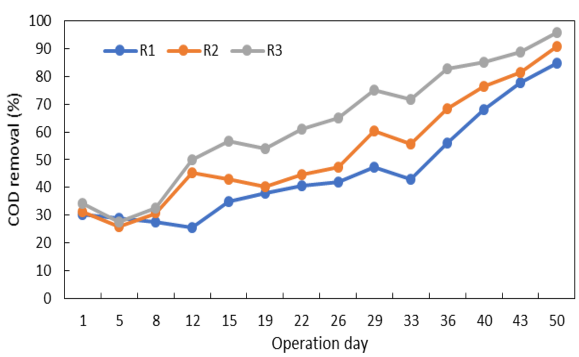


Figure 5. COD removal in R1, R2 and R3

CONCLUSIONS

Performances of reactors were observed for all the examined parameters. On day 50, with 8 g of palm frond biochar in R3, the mean diameter of granule was observed at6.51 mm which was consistently larger than the granule size in R1 (3.69 mm) and R2 (4.16 mm). It proved that an aerobic granulation was enhanced through the addition of biochar. Biochar has shown to be an effective way to initiate granule formation for complete sludge granulation, especially for SBR system. Lower SVI (49.7 mL/g) was achieved in R3 on day 47 than SVI in R1 (83.1 mL/g) and R2(79.1 mL/g) which proved that R3 showed good sludge settling. The biomass concentration (MLSS and MLVSS) in R3 was 12450 mg/L and 11550 mg/L higher than R1 (6500 mg/L and 5567 mg/L) and R2 (6500 mg/L and 4450 mg/L). The COD removal efficiency of R3 was 95.8% higher than R1 (84.7%) and R2 (90.8%). The increase of COD removal efficiency in R2 affected by increasing dosage of PFB. Therefore, the granules enhanced by PFB dosage of 8g showed good sludge settling, high biomass concentration and excellent COD removal. From an engineering field point of view, aerobic sludge granulation with the addition of biochar in aerobic granular sludge system is a promising process that potential to lead the next generation of biological wastewater treatment technologies.

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