THE EFFECT OF STATIC MIXER FOR AEROBIC BIOGRANULES FORMATION FOR TEXTILE INDUSTRY WASTEWATER TREATMENT

S. Sulaiman[1], A. Aris[2], A. R. Abdul Syukor[3], K. Muda[4]

[1,3]Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang, 26300 Kuantan, Pahang, Malaysia.
[2,4]Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia.

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ABSTRACT

Two identical sequencing batch reactors (SBRs) namely R1.4N and R1.4Y were operated at superficial air velocity (SAV) of 1.4 cms^{-1} to investigate the influence of static mixer on aerobic granulation. Reactor R.14Y was added with a static mixer. The formation of aerobic granules with good settling properties were observed in R1.4Y showing SVI and SV of 29.5 mLg^{-1} and 80.4 mh^{-1}, respectively, with high accumulation of biomass concentration in the reactor (7.18 gL^{-1}). The SBR system also demonstrated good removal efficiency of chemical oxygen demand (COD) and color of 94.2% and 63.1%, respectively. Therefore, it appears that static mixer could enhance the biogranulation process treating textile wastewater.

KEYWORDS*: Aerobic biogranules; static mixer, SAV; SBR; textile wastewater*

1.0 INTRODUCTION

Aerobic granulation is a self-immobilisation process from sludge to compact granules. This technology comes out to be a promising technology due to its capability in treating various type of wastewater. Aerobic granulation is affected by various number of operational parameters such as hydrodynamic shear force, organic loading rates, hydraulic retention time, settling time, dissolved oxygen and volume exchange rate. One of the most influencing factors that has received consideration is hydrodynamic shear force; typically quantified by SAV. Most of the biogranulation studies have reported the use of SAVs that

* Corresponding Email: suryati@ump.edu.my

was much higher than 1.2 cms^{-1} to obtain the required hydrodynamic shear force necessary for the success of the granulation process (Beun et al., 1999; Tay, Liu & Liu, 2001; Chen, Jiang, Liang & Tay, 2008; Lochmatter, Gonzalez-Gil, Holliger, 2013). Such SAVs normally require high aeration rates which results in high energy consumption and eventually operational cost. More recently, few researches have been reported on the use of low SAV in biogranules development.

Using SAV of about 0.42 cms^{-1}, stable granules were sucessfully in treating acetate (Henriet, Meunire, Henry & Mahillon, 2016), while Devlin, di Biase, Kowalski and Oleszkiewiez (2017) observed the formation of stable granules treating low-strength wastewater under SAV of 0.41 cms^{-1}. In an attempt to apply low SAV in biogranules development, a study was carried out to develop biogranules using static mixer. As the application of static mixer on biogranules formation is apparently mixing, this study aimed to determine the influence of static mixer the process of biogranules development. The information derive from this study can offer insights on the role of static mixer in the development of biogranules in treating textile wastewater.

2.0 MATERIALS AND METHOD

2.1 Wastewater composition

A synthetic textile wastewater with the following compositions described by Muda et al., (2010) was used as the influent wastewater: NH_4Cl 0.16 gL^{-1}, KH_2PO_4 1.42 gL^{-1}, K_2HPO_4 0.58 gL^{-1}, $CaCl_2.2H_2O$ 0.18 gL^{-1}, $MgSO_4.7H_2O$ 0.09 gL^{-1}, EDTA 0.02 gL^{-1}) and trace element solution was used according to Smolders et al. (1995) (H_3BO_3 0.15 gL^{-1}, $FeCl_3.4H_2O$ 1.5 gL^{-1}, $ZnCl_2$ 0.12 gL^{-1}, $MnCl_2.4H_2O$ 0.12 gL^{-1}, $CuCl_2.2H_2O$ 0.03 gL^{-1}, $NaMoO_4$ 0.06 gL^{-1}, $CoCl_2.6H_2O$ 0.15 gL^{-1} and KI 0.03 gL^{-1}). A total concentration of 50 mg L^{-1} of Reactive Blue 4, Reactive Black 5 and Disperse Red 13 from Sigma-Aldrich, representing the common dyestuff used in textile industry were used as mixed dyes. The COD of the synthetic wastewater was 1500 mgL^{-1} giving organic loading rate (OLR) of 2.2 kg COD $m^{-3}d^{-1}$. All rectors were inoculated with 750 mL of seed sludge obtained from Sewage Treatment Plant at Taman Harmoni, Johor.

2.2 Reactor set-up

The experiment was conducted for 70 days in two laboratory-scale sequencing batch reactors (SBR). SAV of 1.4 cms^{-1} was used for both reactors. The first reactor was run without static mixer (labelled as R1.4N) and the other one was equipped with a static mixer (labelled as R1.4Y). Each reactor has a total height and internal diameter of 100 cm and 8 cm, respectively and a working volume of 1.5 L. The influent was fed from the bottom port of the reactor and the effluent was withdrawn at 15 cm from the bottom giving a volumetric exchange ratio of 50%. Fine air bubbles were introduced by a diffuser located at the bottom of reactor. The static mixer in R1.4Y was a fixed stainless steel bar which had welded branches. A schematic diagram representation of the reactor set-up for R1.4Y is given in Figure 1.

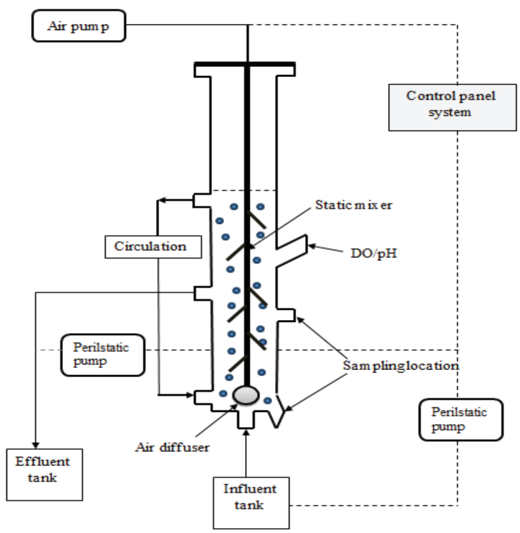


Figure 1. The schematic diagram of bioreactor system with static mixer

2.3 Analytical methods

The formation of biogranules was determined using a stereo microscope equipped with digital image analyzer (I-Solution Premium). Mixed liquor suspended solid (MLSS) was measured by collecting the water sample from reactors. The granules developed in the SBR column were also periodically collected and analyzed for their physical characteristics including sludge volume index (SVI), settling velocity (SV) and strength. The SVI procedure was carried out by measuring the bed volume of a well-mixed sample after 30 minutes of settling divided by the dry weight of the biomass in the reactor (de Kreuk, Pronk & Van Loosdrecht, 2005). The settling velocity experiments were conducted based on Zheng, Yu, Liu and Liu (2006) by recording the time taken for the granules to drop from a certain height in a measuring cylinder. The granular strength index was expressed as integrity coefficient (IC) and was determined following the test procedure described by Ghangrekar, Asolekar and Joshi (2005). The lower value of the IC higher shows the higher strength of the granules. Other parameters such as COD and color were analyzed for system performance according to Standard Methods. The performance of R1.4N and R1.4Y were compared by Paired-samples T-test. The statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 21. A *P*-value of less than 0.05 were considered as statistically significant.

2.4 Experimental procedure

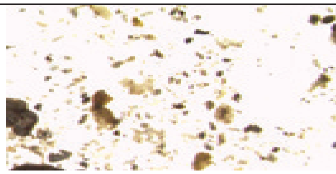
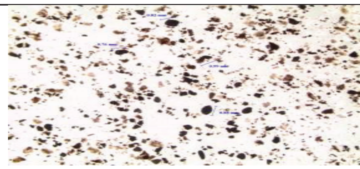
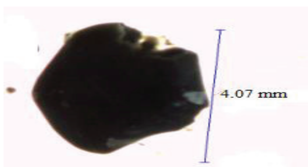
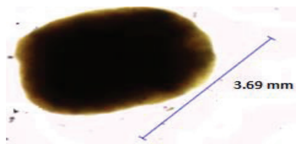
During the start-up period, 750 mL of seed sludge and 750 mL of synthetic textile wastewater were added into the reactor system making the initial MLSS concentration of 2 gL^{-1}. The seed sludge appeared like a fluffy loosed structure with brown color. For each cycle, 750 mL of synthetic wastewater were fed into the reactor during the fill phase. The reactors were operated with intermittent phase in an 8 hours cycle time which consisted of filling (5 min), anaerobic (220 min), aerobic (240 min), settling (5 min), idle (5 min) and decant (5 min). Aeration took place only during the aerobic-react phase of the sequencing batch reactor cycle, when air was forced through the fine air bubble diffuser. The aeration rates for the reactors were 4 $Lmin^{-1}$, which corresponds to SAV of 1.4 cms^{-1} giving DO concentrations between 4 and 8 mgO2 L^{-1}. The OLR of 2.2 kgm-3d^{-1} was applied in all reactors throughout the development stage. Reactors were operated at room temperature (20-30°C).

3.0 RESULTS AND DISCUSSION

3.1 Biogranules formation

The seed sludge to both reactors had a typical form of sludge with fluffy and irregular structure. The formation of small granules in both reactors could be seen between day 15 to 30. Biogranulation in R1.4Y occurred at a faster rate than those in R1.4N. As soon as granulation process started, biomass growth on the wall diminished. Finally, after 70 days of the operations as can be seen in Table 1, the mean size of biogranules in R1.4N achieved 4 mm while the mean size of biogranules in R1.4Y were slightly smaller (3.7 mm). After reaching the maximum mean size, the granules increased in size diameter due to strong shear force and mixing produced by static mixer. This result implied that the presence of static mixer had promoted granule formation by allowing aggregates to form earlier.

Table 1. Granules formation from seed sludge to mature granules

Characteristics	R1.4N	R1.4Y
Seed sludge		
Mature granules		

3.2 Biomass profile and settling properties of biogranules

The relationship between biomass concentration, SVI and settling velocity of the granules is summarised in Figure 2. The performances of settling properties of the developed granules reflect the biomass concentration in a system. Apparently, the biomass concentration in both reactors showed a similar trend in which, the MLSS concentrations were higher during the reactor start-up but later decreased after a week of operation due to washout of poor settleability of sludge.

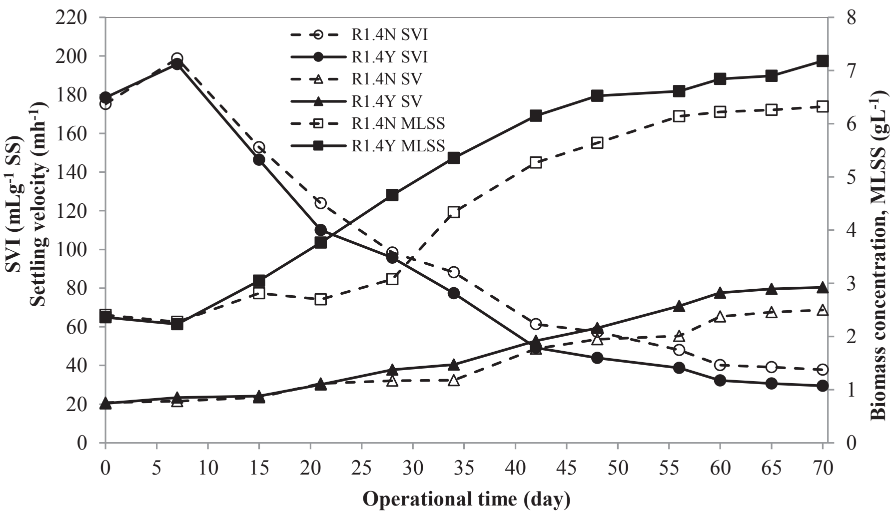


Figure 2. Change in granules properties during the development in the SBR

Smaller granules were observed earlier in R1.4Y on day 15, most probably attributable to the reason of having a static mixer in the reactor. A significant difference on biomass concentration can only be seen after 20 days of operation where reactor R1.4Y had a higher biomass concentration in comparison with R1.4N. An increasing trend were observed and reached 6.32 gL^{-1} of MLSS for R1.4N and 7.18 gL^{-1} of MLSS for R1.4Y on day 70 as shown in Figure 2.

The increasing of setteability of granules in both reactors was supported by the increased of settling velocity and decreasing values of SVI. As can be seen from Figure 2 during the initial stage, the settling velocity and SVI values decreased due to severe biomass washed out in the effluent as the seed sludge had a low settling velocity. After 28 days of operation, settling velocities of R1.4N and R1.4Y were respectively 32.1 mh^{-1} and 37.8 mh^{-1}, and these values continued to increase untill day 70 (1.4N-68.7 mh^{-1} and R1.4Y-80.4 mh^{-1}). It is clearly shown that the settling ability of the granules from R1.4Y improved more than those of R1.4N. In addition, the reduction values of SVI were also observed as improvement of granules development. The SVI of granules in R1.4N (37.8 mLg^{-1}) on day 70 was obviously higher than in R1.4Y (29.5 mLg^{-1}) which confirmed that static mixer had an influence on the granules development. As reported by Long et al. (2014), biogranules with SVI value of less than 52 mLg^{-1} indicates that the cultivated granules possess good settling properties.

Figure 3 compares the strength of the granules in R1.4N and R1.4Y. The lower integrity coefficient indicates the higher the strength of granules. The strength of granules in R1.4Y has improved than that of R1.4N as the IC on day 20 for the former was 49.6% as compared to 52.5% for the latter. At the end of the experiment, the IC for the granules in R1.4N and R1.4Y were 34.7% and 27.5%, respectively. These values are lower than the values that were reported by Liu, Xu, Yang and Tay (2003) which is in the range of 77-99%. At this point, granules cultivated in this study were completely comparable with those granules reported by Muda et al. (2010). With higher shear force due to the presence of the static mixer, the biogranules in R1.4Y had higher strength as compared to R1.4N.

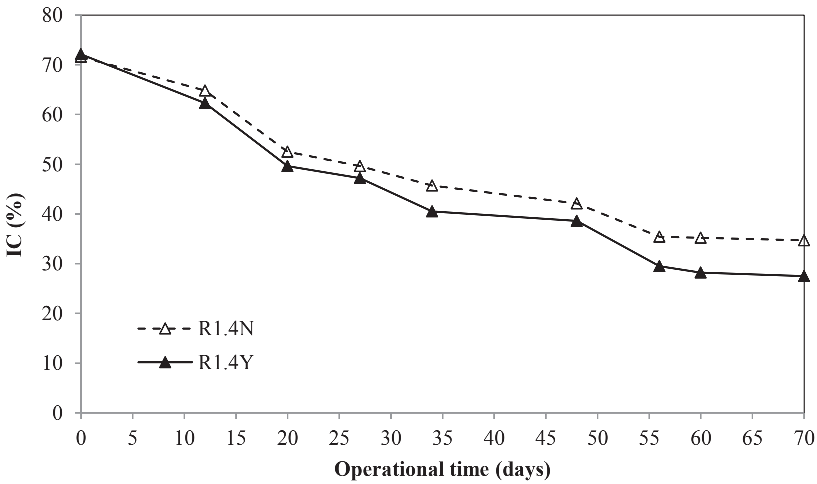


Figure 3. Granules strength during the development stage in SBR system

Paired-samples T-test analysis revealed that there was a significant difference between R1.4N and R1.4Y with respect to MLSS, SVI, settling velocity and IC. As given in Table 2, the mean concentrations for R1.4N is 4.45 slightly lower than that of R1.4Y (m=4.70) at significance level P=0.04. There was a significant difference in SVI and granules strength, IC between the reactor without static mixer, with P=0.001. With respect to settling velocity, there were also a significant difference between the reactor without static mixer and with static mixer (P<0.05). The mean value for R1.4N is 43.33 while R1.4Y is 49.74 and at significant level P=0.002. The statistically analysis shows that application of the static mixer in the reactor managed to develop biogranules with better characteristics as compared to the one without static mixer.

Table 2. Paired-samples T-test analysis on biomass profile and granules properties

Reactor	MLSS (gL^{-1})		SVI (mLg^{-1})		SV (mh^{-1})		IC (%)	
	Mean	*P*	Mean	*P*	Mean	*P*	Mean	*P*
R1.4N	4.45	0.04	93.43	0.001	43.33	0.002	47.96	0.001
R1.4Y	4.70		85.65		49.74		43.94	

3.3 COD and color removal performance

Figure 4 illustrates the COD and color removal efficiency in the reactor R1.4N and R1.4Y during the development stage. COD removal for both reactors were lower during the initial 7 days, most probably due to low MLSS in the reactors and some adaptation period was necessary for the seed sludge to effectively treat the synthetic wastewater. From day 15 onwards, the removal in R1.4N and R1.4Y were increased and stabilized at 94.2% and 93.2%, respectively at the end of the experiment. On the other hand, low color removal of 40.8% for R1.4N and 44.6% for R1.4Y were observed in the first two weeks. After the granules had appeared on day 15, the color removal efficiencies increased to 50.4% and 54.5% on day 28 and later stabilized at 60% and 63.1% for R1.4N and R1.4Y, respectively on day 70. In general, there was not much different in terms of COD and color removal for both reactors.

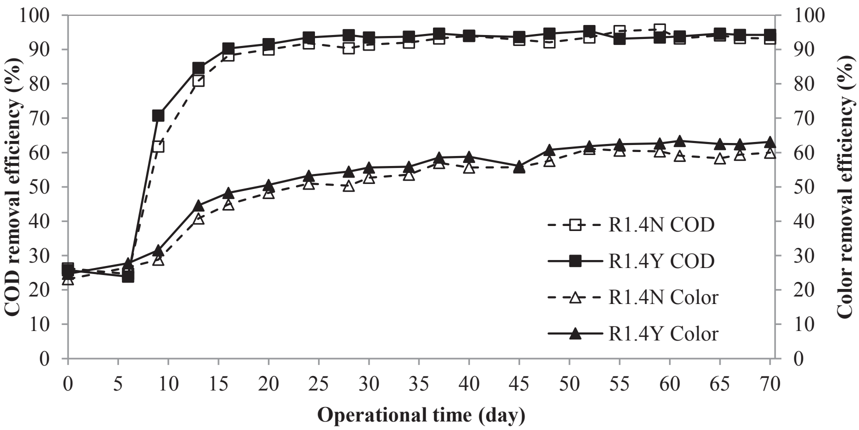


Figure 4. Removal performance of the granules during the development stage in SBR

4.0 CONCLUSION

Results obtained from this study have demonstrated that static mixer influenced the granulation process. Biogranules were succesfully developed during the treatment of the textile wastewater. Better results were obtained when applying static mixer where biogranules have better settling properties (SVI and SV of 29.5 mLg^{-1} and 80.4 mh^{-1}) and removal performance (COD and color removal of 93.2% and 63.1%). Future study is needed to compare the operation cost when applying static mixer in an SBR.

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