Effects of Varying Filling Ratio of Attach Growth Media on the Performance of Moving Bed Bioreactor

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***Abstract*:** *The moving bed biofilm reactor (MBBR) has been an efficient technology for urban and industrial wastewater treatment. The filling ratio contributes to the performance of MBBR. This study investigates the effect of varying filling ratio on MBBR performance in treating sewage. A 3-liter lab-scale MBBR was fed with low organic loading rate using sewage. The system operates at a DO level of 2mg/L and a hydraulic retention time of 8 hours. Acclimatization took place for about two weeks. The movement of the carriers was generated by aeration. The specific surface area of MBBR carriers used was 500 m2/m3 with filling ratio of 25%. Experiment was repeated using 50% filling ratio and the wastewater quality analyzed includes COD, TSS and turbidity according to APHA method. Results revealed that the performance of MBBR filled with 25% filling ratio achieved removal with TSS and turbidity of 85%, and COD 76%. On the other hand, higher percentage of removal were observed by the MBBR filled with 50% filling ratio with TSS, turbidity and COD of 92%, 88% and 81%, respectively. This evident the large surface area of the biofilm that enables the media to efficiently adsorb a high amount of substrates from the influent wastewater.*

Keywords: *Moving bed biofilm reactor, biofilm carrier, sewage, filling ratio*

1. Introduction

The MBBR technology, claim to be highly effective biological treatment process which is also known as a hybrid process due to its combination of the activated sludge process and incorporation of the floating plastic carriers [1]. The system can be used for municipal and industrial wastewater treatment, aquaculture, portable water denitrification, secondary and tertiary application. [2], [3]. The carrier plays an important role in increasing the surface area, which allows the biological microorganism to attach to and grow in the aeration tank. The increased surface area reduces the footprint of the tanks required to treat the wastewater. The biofilm plastic media carrier elements can vary in size and shape but they usually have densities slightly less than the density of water so they can float and be suspended in the water to be treated [4]. The use of biofilm systems also enhances the control of reaction rate and population mechanisms [5].

There are several factors that influence the performance of the MBBR process including the reactor process operation such as loading rate, feeding composition, HRT and biofilm thickness [6]. The filling ratio is the percentage of the reactor volume occupied by the biological carrier. Low filling ratios generally mean easier mixing, easier aeration and easier oxygen uptake. However, low filling ratios also mean there will not be enough microorganisms due to the low amount of carriers. On the other hand, high filling ratio generally means more surface area for microorganisms to grow on which leads to better contact and treatment. However, too high filling ratio may cause mixing problems and clogging problems. It is therefore important to be able to operate at the optimum filling ratio. Hence the objective of this study is to investigate the variation of filling ratio of the plastic carrier in the MBBR process. A steady-state condition is assumed to evaluate the performance of the MBBR in this study.

https://doi.org/10.17758/ERPUB5.ER0919270

2. Materials and Methods

2.1. The MBBR System

A laboratory scale MBBR system with a 3-liter working volume seeded with 2000 mg/L of MLSS was used in this study. The MBBR set up flow diagram is as shown in Figure 1. The reactor was operated at room temperature. The concept of the MBBR process is that the floating plastic media carrier provide a platform for the microbial growth in a totally mixed reactor. The air diffusers were installed at the bottom of the reactor to provide oxygen. Dissolved oxygen was maintained to be at more than 2mg/L and pH level between 7 to 8 throughout the experiment.

The reactor was filled with the plastics carrier to filling ratios of 50%. The plastic media carrier used is made of polyethylene and has a density of about 0.92-0.96 g/cm3 and a specific surface area of 500 m2/m3 with a diameter of 25 mm and length of 12 mm. The carriers are shaped like little cylinders and have rough edged outer surface. These media are moving freely in the reactor caused by the introduced air at the bottom of the reactor to provide oxygen. The hydraulic retention time used in this study is 8 hours. The separation efficiency and performance of a MBBR is greatly influenced by the hydraulic retention time to ensure the microorganisms attached to the media have enough contact time with the wastewater before discharge. Experiment was repeated using filling ratio 25%.

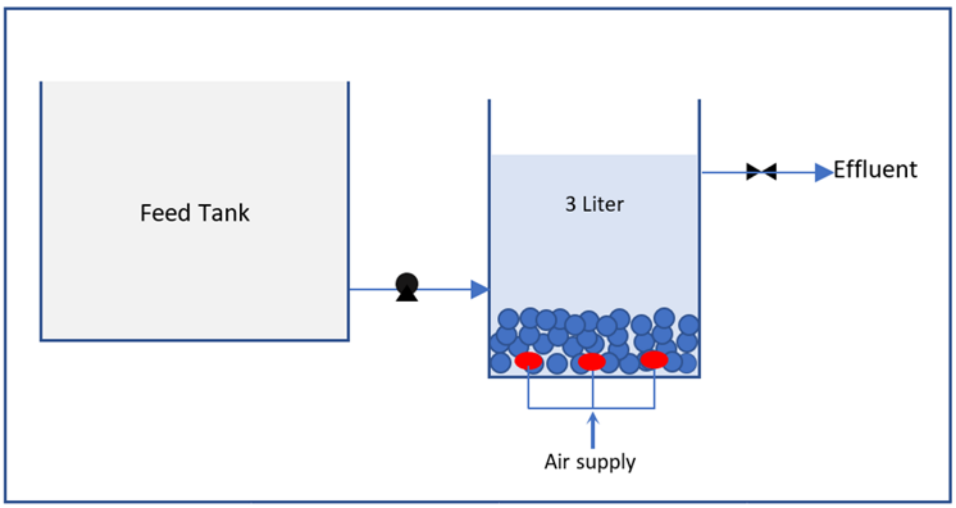

Fig. 1: Lab scale MBBR flow diagram

2.2. Analytical Methods

The wastewater and activated sludge samples were collected from sewage treatment plant located in Selangor, Malaysia. The samples were transferred immediately to the laboratory and stored at 4oC to avoid any physical-chemical changes in the wastewater. Chemical oxygen demand, total suspended solids and turbidity were analyzed according to APHA method [7] to obtain the performance of MBBR.

3. Results and Discussion

Dissolved oxygen levels in the MBBR must be maintained higher than 2 mg/l for optimal BOD/COD. This is important as proper aeration is necessary to maintain aerobic conditions needed by the microorganisms. Decreasing the DO in the tank to 1 mg/l reduced the BOD/COD separation efficiency by 13% [8]. The plastic media carriers are kept in the MBBR to ensure that biomass is contained in the process. Due to this, MBBRs can be operated at shorter HRTs, and are therefore considerably more compact, compared to activated sludge systems [9].

3.1. Biofilm Formation

After a two-week acclimatization period, the experiment began. The experiment was carried out to determine the effects different filling ratios will have on a moving bed biofilm reactor (MBBR). The constant operating conditions were the hydraulic retention time of 8 hours and MBBR volume of 3L. Biofilm formation on MBBR carriers follows the four stages of attachment, accumulation, re-generation and maturation [10]. The growth patterns of biofilms are, dynamic and is practically impossible to reproduce a specific biofilm growth pattern [11]. As biofilms grow on the MBBR carriers there is a continuous detachment of biomass caused by abrasion, erosion, sloughing, and predator grazing [12]. Figure 2 and Figure 3 show the plastic media carrier before and after the biofilm formation.

Fig 2: Plastic media carrier without biofilm

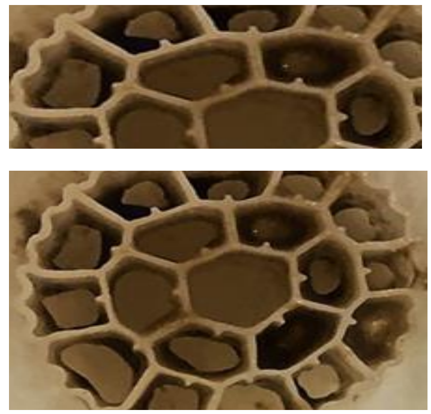

Fig 3: Biofilm on plastic media carrier

3.2. Overall MBBR Performance

The 50% and 25% filling ratio were able to achieve good chemical oxygen removal percentage. The 25% filling ratio achieved a maximum chemical oxygen removal percentage of 79.53% while the 50% filling ratio achieved a maximum chemical oxygen removal percentage of 83.85%. On average the 50% filling ratio achieved a COD removal of 81% while the 25% filling ratio achieved a COD removal of 76%.

The 50% filling ratio clearly provides a better COD removal efficiency. This is because using 50% filling ratio in the MBBR provides twice as much biological carriers as 25% filling ratio. This means that there is more opportunity and room for biological attachment. The 50% filling ratio will provide more biomass population compared to the 25% filling ratio. Therefore, it will lead to a better treatment as there is more oxidation of organic matter going on. Figure 4 shows the overall performance of the MBBR process.

Table 1 shows the comparison between the removal efficiency of 25% and 50% filling ratio. Although the reactors may be operated at similar loading rates and mixing intensities, effluent concentrations and reactor hydrodynamics will depend on the activity in the reactors and on the movement of the carriers, which in turn may be affected by carrier design and filling degree. When these conditions differ, substrate availability to the biofilms will vary, resulting in different biofilm performance in the different reactors [6]. Another study investigating chemical oxygen demand removal found out that the COD removal percentage was 80.39% at 40% filling ratio [13](Shrestha, 2013). This correlates closely to values gotten in this study. In Shahot's study of biofilm efficiency using spherical carriers, the plant achieved a chemical oxygen demand removal of 80% [14]. This also correlates closely to values gotten in this study.

Both the 25% filling ratio and 50% filling ratio achieved very good suspended solids removal. The 25% filling ratio achieved a maximum suspended solids removal of 86% while the 50% filling ratio achieved suspended solids removal of 97%. On average the 50% filling ratio achieved a TSS removal of 92% while the 25% achieved a TSS removal of 85%.

The 50% filling ratio also provides higher treatment efficiency in TSS removal which can be seen in Figure 7. This is so because the 50% filling ratio provides more carriers and therefore can absorb and hold on to suspended and dissolved solids in the reactor. In Malaysia Department of Environment's standard B, the maximum discharge limit for TSS is 50 mg/l. Both 50% and 25% filling ratio were able to meet this requirement. This can be seen in figure 9.

After extensive research into other study to find total suspended solids removal, the figures gotten in this treatment were found to be consistent and, in some cases, better than other study. The effectiveness of biofilm treatment using spherical carriers was studied by Shahot and the total suspended solids removal was found to be 80% [14].

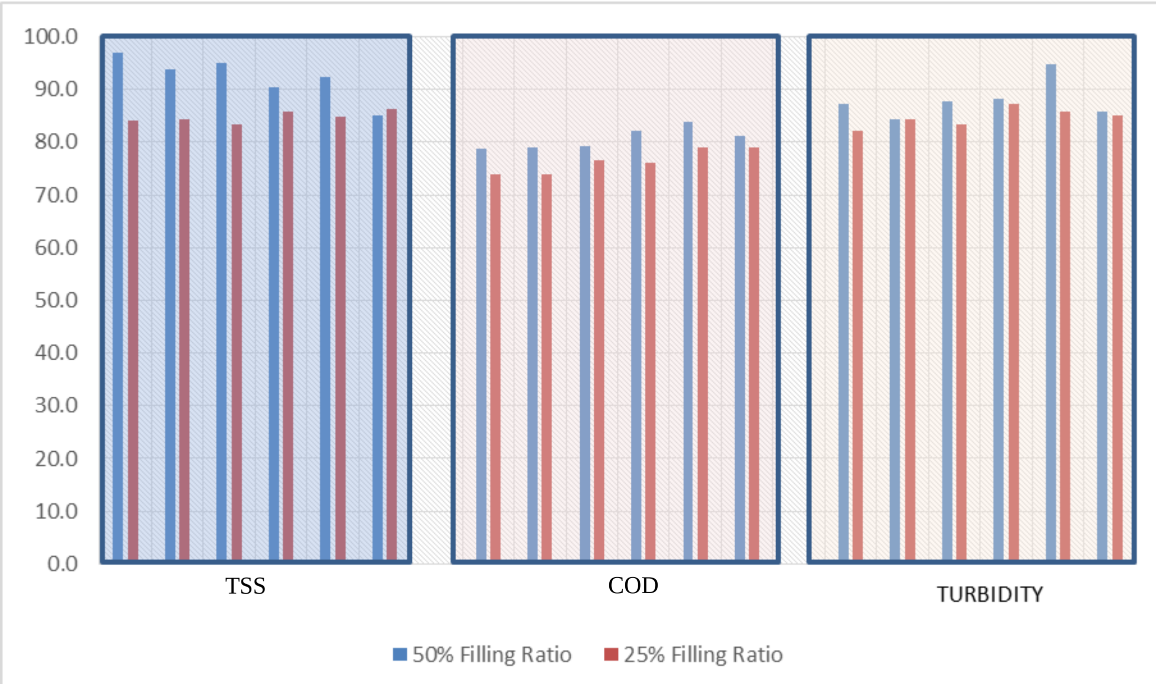

Fig. 4: Overall performance of MBBR at filling ratio 50% and 25%

The final parameter tested was turbidity. The maximum turbidity removal achieved by the 50% filling ratio was 95% while the 25% filling ratio achieved a maximum turbidity removal of 87%. On average, the 50% filling ratio achieved a turbidity removal of 88% while the 25% filling ratio achieved an average turbidity removal of 85%. It can be seen that the 50% filling ratio also provides better treatment efficiency for turbidity removal.

TABLE I: Influent and Effluent data over time

Time, day	Turbidity				COD				TSS			
	50		25		50		25		50		25	
	Effluent	% Removal	Effluent	% Removal	Effluent	% Removal	Effluent	% Removal	Effluent	% Removal	Effluent	% Removal
1	11.93	88.16	22.75	82.23	179	78.74	210	73.75	20	96.85	19	84.17
3	14.20	87.65	18.89	83.43	198	78.94	208	73.93	33	93.89	22	84.29
5	19.35	87.15	25.77	84.38	170	79.29	200	76.47	10	95.00	25	83.33
7	9.80	94.92	23.66	87.16	140	82.17	190	76.07	10	90.48	25	85.71
9	31.50	84.37	27.98	85.87	150	83.83	187	79.08	15	92.31	31	84.88
11	31.00	85.78	31.31	84.99	132	81.14	166	79.53	18	85.00	29	86.19

4. Conclusion

This study showed that 50% filling ratio was found to improve the performance of the moving bed biofilm reactor with maximum removal efficiency of 83.85% COD, 96.85% TSS and 94.92% turbidity. Reducing the filling ratio to 25% reduced the efficiency to 79.53% of COD, 86.19% of TSS and 87.16% of turbidity. Comparisons were made with various similar studies and the results gotten in this study was found to be consistent with the other studies. Filling ratio of 50% was found to be the optimum filling ratio of plastic media carrier.

5. Acknowledgements

This study is fully funded and supported by Segi University, Kota Damansara, Malaysia

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