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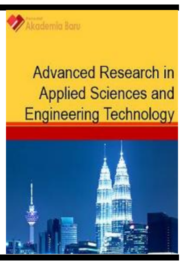

Submerged Bed Biofilms Reactor (SBBR) for Industrial Wastewater Treatment

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ABSTRACT

Oleochemicals industry consumes large amount of water and chemicals for processing crude oil that contain high chemical oxygen demands (COD). Thus, the discharge wastewater containing high COD concentration is the major factor that contribute to water pollution. An effective wastewater treatment is required before discharge to environment. Lab scale submerged bed biofilms reactor (SBBR) was operated continuously for the treatment of Oleochemicals wastewater. Cosmoballs® packing with carrier A (green sponge) were used for bacteria growth in the SBBR. Water analysis such as chemicals oxygen demand (COD), pH and Turbidity were analysed. The optimum condition for SBBR when Cosmoball® carrier and carrier A were used as packing materials with flowrate of 100ml/min and 1:1 ratio of activate sludge (mixed culture) volume to SBBR volume. The results indicate that COD was reduced, initially 6000 ppm to 140 ppm while turbidity and pH after treatment were recorded as 9.0 and 7.0 respectively which were fulfilled requirements by Department of Environment (DOE) Malaysia.

Keywords:
Industry effluent; oleochemical plant; cosmoball®; biofilms; Chemical Oxygen Demand (COD); submerged Bed Biofilm Reactor (SBBR)

1. Introduction

Oleochemicals plants commonly producing fatty products like vegetable and animal technical greases and technical fatty acids. Generally, this oleochemicals industry located at the rural areas and their products are designed for the biodiesel production, surface active agents (SAA) synthesis, feed

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enrichment, and cosmetic industry. Postproduction of animal fats and fats from plant origin are the basic raw materials that used for oleochemicals production [1].

The main problem faced by oleochemicals industry is the treatment and disposal of their wastes. The oleochemicals wastes can be classified as wastewater and glycerin pitch. Glycerin pitch is a viscous liquid coloring brown to dark brown with the average COD of 1 to 2 million per liter. This glycerin pitch disposal contains high organic compound that lead to difficulties of biological degradation. Dilution of glycerin pitch with wastewater helps reduce the COD before wastewater treatment [2].

The activated sludge process is commonly used biological wastewater treatment for domestic and industrial wastewater. Aeration tank and settling tank are two of important units for continuous flow activated sludge system. The biochemical reactions associated with the removal of the organic matter take place in the biological reactor (aeration tank). The biomass develops by using the substrate present in the influent wastewater. The biomass settling that leads to a clarified final effluent take place in the secondary sedimentation tank. On the other hand, a part of the biomass at the bottom secondary sedimentation tank is recirculated to the aeration tank in order to maintain a large biomass concentration in aeration tank for high efficiency of the system [3]. Although the activated sludge process is more compact, but still requires large areas for the construction of aeration tanks and sludge settlers. Available area may be a limiting factor in oil refinery industries, especially if they are located in densely populated areas without enough space for expansion [4]. This conventional biological wastewater treatment in oleochemicals industry is inefficient and use up industry's time and resources.

SBBR is one of the biofilms technology that had been proven by previous researcher that is good in contaminant removal. SBBR is based on the aerated submerged fixed open structured plastic carrier to support biofilms growth. Compared to activated sludge system, this system has a smaller layout area, more microbial population, strong impact resistance, more stable ecological system in wastewater treatment, and higher efficiency in wastewater treatment [5]. Besides, this SBBR is simple to control and maintain, reduce room usage, lower costs, and minimize odor and noise [6]. On top of that, this SBBR system also has high stability of microorganisms that enable on removing pollutant, much higher biomass content, and less surplus biomass or sludge [7].

Furthermore, cosmoball® carrier chosen as the carrier inside the SBBR with the combination of carrier A (green sponge). Cosmoball® carrier is suitable for both aerobic and anaerobic conditions. This carrier is light in weight made from strong polyethylene plastics which can resist even highly corrosive or hazardous effluent. On top of that, the uniqueness design of this carrier makes it less prone clogging as the void spaces provided in excess of 85% [8].

Previous studies show that cosmoball® carrier was used effectively in the industrial wastewater treatment (textile wastewater) that successfully to reduce COD to approximately about 60% [9-10]. Furthermore, similar studies showed about 80% of COD reduction for sewage treatment plant [8]. Moreover, 50% filling ratio of cosmoball® carrier in the reactor is the optimum condition for COD reduction based on the previous study [11].

The first scope of this research is fabricated laboratory scale of Submerged Bed Biofilm Reactor (SBBR) system for industrial wastewater treatment. Secondly, Test of cosmoball® carrier packed with carrier A in three different hydraulic retention time for treating industrial wastewater. Thirdly, comparison of the quality of wastewater which is Chemical Oxygen Demands, pH and Turbidity before and after the treatment by using water quality analysis. The aim of this research is to improve and utilize hydraulic retention time for biological wastewater treatment. To achieve this, the research is done with the following objective which is to determine the effectiveness of cosmoball® carrier with combination carrier A in different hydraulic retention time (HRT) to treat oleochemical wastewater.

2. Materials and Methods

Wastewater sample was obtained from Natural Oleochemical (NatOleo) Sdn. Bhd. that located in the Pasir Gudang Industrial area, Johor, Malaysia. The fabricated lab scale of SBBR was installed in the effluent treatment plant (ETP) at NatOleo. This fabricated SBBR place right after the chemical treatment in the ETP NatOleo. Continuous flow wastewater from the chemical treatment act as the influent to the SBBR lab scale. Table 1, shows the characteristics of the oleochemicals wastewater sample after going through chemical treatment taking from ETP NatOleo.

Table 1
Characteristics of the Wastewater

Characteristics	Value
Flowrate, m3/day	100
Chemical Oxygen Demands, mg/L	6000-10000
Biological Oxygen Demands, mg/L	1000-2000
Temperature,	<60
pH	8-10
Suspended Solids, mg/L	200-400
Oil and Grease, mg/L	1000

The fabricated lab scale SBBR was made from Perspex glass that has a thickness of 5.0mm. Perspex glass was used because this type of material was easy to handle, low cost and transparent. Three SBBR tank were connected serially using tubes that allow wastewater to flow continuously throughout each tank. Each tank has the dimensions of 30.0 cm length, 30.0 cm width and 45.0 cm height. These three SBBR tank were labelled as SBBR1, SBBR2 and SBBR3 as shown in Figure 1 has 121.5 L of working volume. This SBBR system was designed for maximum contact area that would increase the degradation rate of the organic content in the wastewater.

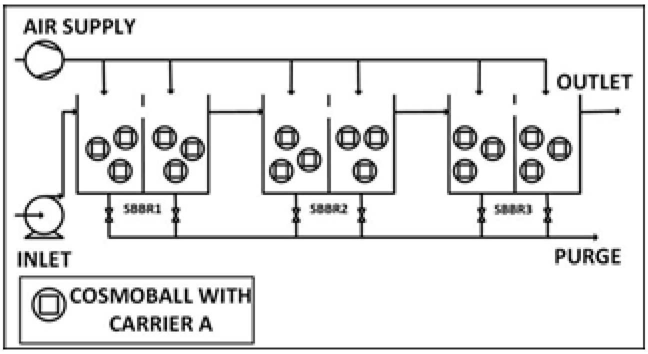

Fig. 1. Experimental Setup for Fabricated Lab Scale SBBR

Figure 2 show carrier A pack inside the cosmoball® carrier to treat the wastewater in the SBBR system. Carrier A is green rectangular sponge pads that have rough fabric surface and non -scratches material. Carrier A has dimension of 14.7 cm of length, 9.7 cm of width and 0.7 cm of thickness.

Fig. 2. Carrier A pack inside the Codmoball® Carrier

Next, filling ratio of cosmoball carrier inside SBBR was 50% by volume of the SBBR. SBBR1 was inoculated with the activated sludge (mixed liquor) that was taken from the biological clarifier at the ETP NatOleo. The activated sludge ratio is 1:1 to the reactor volume. The experiment was operated with three different flowrate of 100 mL/min, 200 mL/min and 300 mL/min that pump continuously from the chemical treatment at the ETP NatOleo. Sample of the wastewater in the influent and effluent of the SBBR was analyse daily (every 24hours) at 0900 hour. This wastewater sample were analysed according to the Standard Methods for Examination of Water and Wastewater [12]. Wastewater analysis likes COD, turbidity and pH were analysed daily. The experiment was done three times for each set of experiment to get the average water quality results. Furthermore, this SBBR system were cleaned weekly before run new set of experiment.

2.1 Mathematical Modelling

Mathematical models are used in fundamental research of biological processes to examine the hypothesis, to determine the importance of relationships between variables, to guide the experimental design, and to evaluate the experimental results [13]. Besides, mathematical modelling also was used to determine important variables and critical kinetic parameter [14].

2.1.1 Stover-Kincannon Model

Stover-Kincannon model is one of the ideal mathematical models for describing the substrate removal rate. This equation was used to calculate the reactor volume and effluent organic concentration for the reactor operating in steady sate conditions. The equation was used to study the relationship between specific substrate removal rate versus organic loading rate [15].

In Stover-Kincannon model, the substrate consumption rate for biofilm reactor is presented in equation 1. By linearising equation 1, equation 2 can be obtained.

$$\frac{ds}{dt} = \frac{U_{max}(Q\frac{S_o}{v})}{K_B + (Q\frac{S_o}{v})} \quad (1)$$

$$\frac{v}{Q(S_o - S)} = \frac{K_B}{U_{max}}\left(\frac{v}{QS_o}\right) + \frac{1}{U_{max}}$$

where Umax is maximum substare removal rate (mg COD/L d), Q is inflow rate (L/d), So is influent substrate concentration (mg/L), S is effluent substrate concentration (mg/L), v is reactor volume (L), and KB is saturation value constant (mg/L d).

Then, Umax and KB values can be determined by linear regression of v/Q(So-S) versus v/QSo in which 1/Umax and KB/Umax are intercept and slope of drawing linear graph, respectively.

3. Results and Discussions

Table 2 show the water analysis results for three set of influent flowrates to the fabricated lab scale SBBR. Each set of experiment were done three times to get the average value of the water analysis results. Water analysis like COD, turbidity and pH had been tabulated to get the optimum condition for biological oleochemicals wastewater treatment.

The Chemical Oxygen Demand (COD) influent to the fabricated lab scale Submerged Bed Biofilms Reactor (SBBR) was 6000ppm. This influent wastewater was after the chemical treatment at the ETP NatOleo industry. Figure 3 shows the results of COD reduction that had the conditions of carrier A (green sponge) packed in the cosmoball® carrier, 1:1 ratio of sludge volume, 1:1 ratio of filling ratio cosmoball® carrier inside SBBR, and three different influent flowrates. With the flowrate of 100mL/min, the systems capable to reduce the COD from 6000ppm to 140ppm which is about 97% of COD reduction. However, the usage of cosmoball® carrier packed with carrier A with the flowrates of 200mL/min and 300mL/min only capable to reduce COD from 6000ppm to 900ppm and 1500ppm which is about 85% and 75% of COD reduction. The results show that combination of cosmoball® carrier packed with carrier A had large surface area. This large surface area helps to increase the degradation rate of the organic matter in the wastewater. Similar observation was documented which used K1 packing material for combination of hybrid MBR-MBBR where the wastewater had 90% of COD reduction [16]. The stability and long retention time of attached growth bacteria in the SBBR system enable for removal of recalcitrant contaminants [7]. Thus, the present cosmoball® packed with carrier A was more efficient as previous researcher that succeeded to reduce 50% to 90% of COD [17-19].

Next, the average turbidity influent to the fabricated SBBR lab scale was 100 ntu. It was observed in figure 4 that combination of cosmoball® carrier with carrier A for three different sets of influent flowrates (100mL/min, 200mL/min, 300mL/min), each set succeed in turbidity reduction of 91%, 83% and 75%. The results show that the combination of cosmoball® carrier with carrier A acts as home for attached growth bacteria for degradation of contaminant contents in the wastewater, and at the same time acts as filter to the suspended solids [20]. The uniqueness design of the cosmoball® with carrier A make it less prone clogging as the 85% excess of void spaces provide [8]. So, the combination of the cosmoball® and carrier A can help for better COD and turbidity reduction in the wastewater treatment.

Furthermore, figure 5 illustrated that cosmoball® carrier packed with carrier A for each set that had different influent flowrates succeed in achieved neutral pH of 7 after going through the SBBR treatment. This result indicates bacteria that act in dynamic population in order to adjust from slightly in base to neutral in pH. This mixed culture bacteria had a concept of mix well defined microbe with high activity and the risk of contaminated is reduced because the diversity of inoculum can out bet the contaminating organisms [21].

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Table 2
Water Analysis Results

Flowrate (mL/min)	Days	Average COD (ppm)	Average Turbidity (ntu)	Average pH
100 (20.25 hours HRT)	1	300	9	7
	2	160	10	7
	3	140	13	7
	4	190	11	7
	5	270	13	7
	6	230	11	7
	7	170	15	7
200 (10.125 hours HRT)	1	900	23	7
	2	1100	24	7
	3	1200	24	7
	4	1300	23	7
	5	1200	20	7
	6	1450	17	7
	7	1100	18	7
300 (6.75 hours HRT)	1	2100	27	7
	2	1500	25	7
	3	1710	28	7
	4	1750	34	7
	5	1800	30	7
	6	1880	25	7
	7	2000	27	7

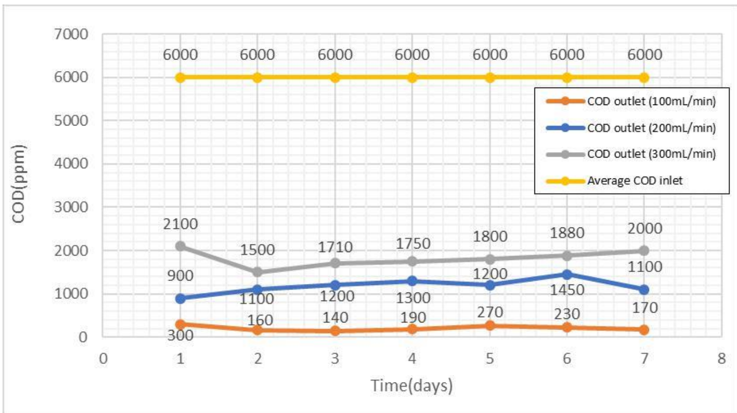

Fig. 3. COD Reduction

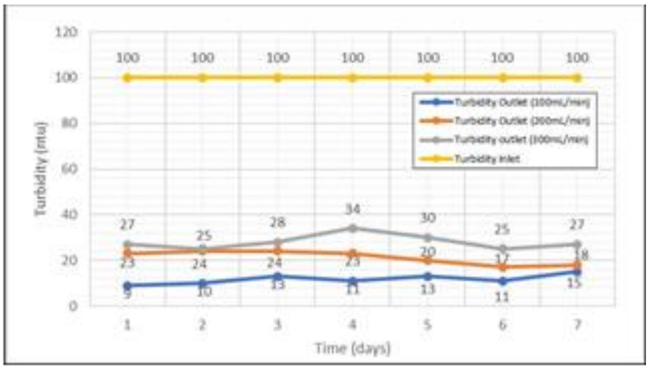

Fig. 4. Turbidity Reduction

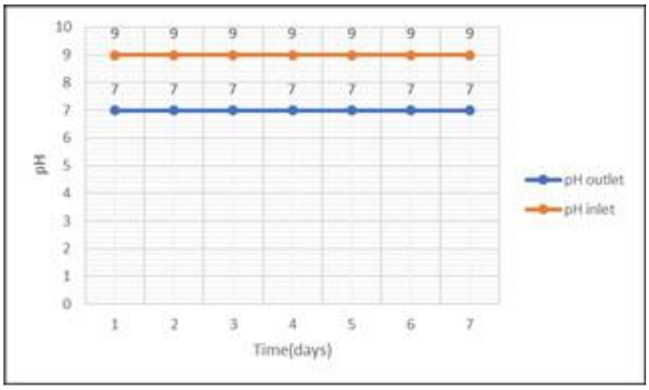

Fig. 5. pH adjustment

Figure 6 shows the graph plotted between reciprocal of total organic loading removal rate, v/Q(So-S), against the reciprocal of total organic loading rate, v/(QSo). The plotted graph of v/Q(So-S) versus v/(QSo) was linear, so linear regression (least square method) was used to determine the intercept and the slope. The straight line contains the intercept, 1/Umax and a slope KB/Umax results from the graph. On the other hand, the saturation value (KB) and maximum utilization rate (Umax) were calculated from the straight line on the graph in the Figure 6. The saturation value constant (KB) and the maximum utilization rate (Umax) were recorded as 29.1329g (L per day) and 34.9650g (L per day), indicating the substrate removed by microorganisms during time and the maximum substrate removed by aerobic organisms versus time, respectively.

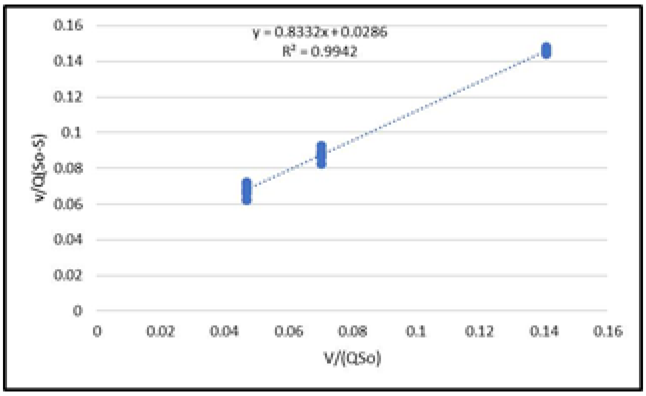

Fig. 6. Stover-Kincannon Model Plot

4. Conclusion

The SBBR wastewater treatment system was demonstrated for its ability to treat oleochemical wastewater treatment with high reduction of COD with 97% reductions, the turbidity 92% reductions and neutralized the pH of the wastewater. The combination of cosmoball® and carrier A for fabricated SBBR lab scale with the condition of 100mL/min has been proven to be the best condition to reduce hydraulic retention time for biological wastewater treatment from 48 hours (conventional treatment) to 20.25 hours.

For mathematical modelling of fabricated SBBR lab scale, Stover-Kincannon model has been applied to this system. The results show that the model gave high correlation of 99.42%. Therefore, these models could be used in the design of the SBBR reactor. The results show the kinetic studies obtained from lab scale experiments can be used for estimating treatment efficiency of full scale reactor under similar operational conditions. On top of that, it is also can be concluded that cosmoball® carrier packed with carrier A could be one of the ideal choice as packing materials in the SBBR system.

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