Preliminary Studies on Oleochemical Wastewater Treatment using Submerged Bed Biofilm Reactor (SBBR)

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Abstract. Wastewater discharge from the industry into water sources is one of the main reason for water pollution. The oleochemicals industry effluent produces high content of chemical oxygen demand (COD) with value between 6000-20,000 ppm. Effective treatment is required before wastewater effluent is discharged to environment. The aim of the study is to develop submerged bed biofilm reactor (SBBR) with packing materials in the cosmoball® carrier. Water quality such as chemical oxygen demands (COD), turbidity and pH were analysed. The result shows that the initial COD of 6000 ppm was reduced below 200 ppm. The optimum conditions for SBBR were obtained when green sponges used as packing material in cosmoball®; effluent flowrate set at 100 mL/min; 1:1 ratio of cosmoball® volume to reactor volume and 1:1 ratio of active sludge (mixed culture) volume to reactor volume. Turbidity and pH were recorded with 9.0 NTU and 7.0 respectively, which indicated that SBBR is feasible as an alternative for conventional biological treatment in oleochemical industry.

1. Introduction
Oleochemicals industry is one of major industries in Malaysia that at some instance produces effluent and affecting the water quality in the environment. This is due to large consumption of mixture of water and chemicals for processing crude palm oil. Without proper treatment, wastewater effluent produced eventually contributes serious and long lasting consequences to human and life [1]. A oleochemical wastewater plant usually generates around of 200 m³ of wastewater daily and mainly comes from the processes of degumming, deacidification, neutralization, bleaching, and deodorization [2]. However, current oleochemicals wastewater treatment is an inefficient, consuming higher hydraulic retention time and use abundant resources [3]. It has been reported that, the treatments are consisting of physical, chemical and biological treatment which consume high hydraulic retention time and requires huge space. Furthermore, activated sludge system which is one type of biological treatment in conventional oleochemical wastewater treatment plant has higher operating costs [4].

In compliance to Environmental Quality Act 1974, which consists of the Environmental Quality (Sewage) Regulations 2009 and Environmental Quality (Industrial Effluent) Regulations 2009, the
water quality index is used to determine the quality of the surface water and the suitability of surface water for irrigation. Based on the designated classifications in the National Water Quality Standards for Malaysia established by DOE [5], the water quality of Chemical Oxygen Demands (COD) should be below 200 ppm before it can be released into the environment.

1.1. Submerged Bed Biofilm Reactor (SBBR)
Submerged biofilms systems including fixed and suspended carriers have been proven highly effective and efficient in removing organic carbon and nitrogen by attached growing biofilms. The system exhibits lots of advantages as compared to semi-batch activated sludge processes. The advantages are stability and long retention time for formation of microorganisms’ biofilm that enables removal of pollutants, much less formation of surplus biomass or sludge [6], needs less air for aeration, can be upgraded to fit increased population, effective for BOD and nitrogen removal with no odor release and quick restarting during power failure [7][8].

1.2. Cosmoball® Carrier
Cosmoball® carrier is a new alternative system used for biological wastewater treatment. Cosmoball® carrier can be used for both aerobic and anaerobic biological treatment that made of strong polyethylene plastics which can resist corrosive and hazardous wastewater [7]. Previous studies show that cosmoball® carrier was used effectively in industrial wastewater treatment of textile wastewater which reduced the COD approximately about 60% [9-10]. Similar studies showed 80% reduction of COD for sewage treatment plant (Ekhmaj, 2012). Installation of new treatment system like cosmoball® in submerged bed biofilm reactor (SBBR) is likely to improve biological treatment in oleochemical plant. In this present study, the cosmoball® treatment system that fitted in SBBR is developed and analyzed for its feasibility and effectiveness in the treatment of oleochemical wastewater.

2. Materials and methods

2.1. Sampling of Oleochemical Wastewater
Samples of wastewater was obtained from Natural Oleochemicals (NatOleo) Sdn. Bhd. that located in the Pasir Gudang Industrial Area, Johor, Malaysia. Meanwhile, at the same location the lab scale of the SBBR was installed with continuous flow of wastewater. Table 1, shows the characteristics of wastewater samples taking from wastewater treatment plant in NatOleo.

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

2.2. Design of Aerobic SBBR Lab Scale
The SBBR was made from Perspex glass with a wall thickness of 5.0 mm. Perspex glass was used because easy to handle, low cost and transparent. Each SBBR tanks has dimensions of 30.0 cm length,
30.0 cm width and 45.0 cm of height. Three SBBR tanks were connected serially using tubes that will allow wastewater to flow continuously.

2.3. Experimental Procedure
The SBBR tank system was labelled as SBBR1, SBBR2 and SBBR3 as shown in Figure 1. The system was designed for maximum reaction and contact area between wastewater and the carrier that will improve the degradation rate of the contaminant content in the wastewater.

![Figure 1. Experimental Setup of the SBBR in the lab scale](image1)

Carrier A as shown in Figure 2 was added inside the cosmoball® carrier to test whether such packing material will improve the quality of Palm Oil Refinery (POR) wastewater. Carrier A is rectangular sponge pads with rough fabric surface and non-scratches material. Carrier A has the size of 14.7cm of length, 9.7cm of width and 0.7cm of thickness. Filling ratio of the cosmoball® inside the SBBR tank was 50% by volume of the tank. Previously, it was observed that 50% of the carrier filling ratio was the optimum condition for this type of treatment [11]. The tank was inoculated with the activated sludge that was taken from the biological clarifier at the NatOleo. The ratio of the inoculated activated sludge to reactor volume is 1:1. The experiment was operated with flowrates of 100 mL/min for the wastewater effluent. Sample of the wastewater was taken daily (every 24 hours) at 0800 hour for the effluent of first SBBR1 and effluent of the third SBBR3. The water quality was analysed daily. The SBBR tanks were cleaned once a week before run the new set of experiment.

![Figure 2. Carrier A pack in the Cosmoball®](image2)

2.4. Analytical Methods
Wastewater effluent in the SBBR1 and SBBR3 were analysed according to the Standard Methods for Examination of Water and Wastewater [12]. The parameters that were analysed; pH, COD and...
Turbidity. The analysis was done trice for each set of experiment to get the average water quality results.

3. Results and discussions

3.1. Treatment Efficiency

As shown in Figure 3, COD effluent after the treatment with and without carrier. COD is a measure of oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant [13]. The initial COD of the oleochemical wastewater after chemical treatment was 6000 ppm. However, by combining carrier A with the flowrate of the 100 mL/min and 50% of sludge volume, the system was capable to reduce the COD effluent to 153 ppm which is about 97% of COD reduction for the first day. The usage of cosmoball® only shows the COD reduction from 6000 ppm to 1700 ppm which is only 71.5% COD reduction. This indicates that large surface area of cosmoball® with carrier A as the packing material helps to increase the degradation rate of the organic matter in the wastewater and similar observation was documented which used K1 packing material for combination of hybrid MBR-MBBR where the wastewater had 90% of COD reduction [14]. The present cosmoball® packed with carrier A was more efficient as previous researcher that succeeded to reduce 50% to 90% of COD [15-17].

Turbidity in the wastewater indicates the amount of suspended materials contained in the wastewater. Too high-suspended solid will eventually clog and increase the turbidity value [18]. However, most of the suspended solids in the oleochemicals wastewater had been removed during the pre-treatment like physical treatment that use to separate solids from the water. Figure 4, shows the turbidity percentage reduction for both cosmoball® and combination of cosmoball® and carrier A from the initial turbidity after chemical treatment. It was observed that by using the combination of the cosmoball® with carrier A and cosmoball® only, both succeed in 92% and 83% of the turbidity reduction for each set. It was hypothesized that the cosmoball® with carrier A not only acted as the home for attached growth bacteria for the degradation of the contaminant in the wastewater but also acted as the filter to the suspended solids [19]. The uniqueness design of the cosmoball® with carrier A make it less prone clogging as the 85% excess of void spaces provided [7]. So, the combination of the cosmoball® and carrier A can help for better COD and turbidity reduction in the wastewater treatment. Table 2 and 3 shows the COD and turbidity analysis of mean and standard deviation for both sets of experiments.

pH is also one of the factors that indicates the water quality and measures the acidity or alkalinity of the water. Figure 5 shows the pH for both set of experiments which is combination of the cosmoball® and carrier A and cosmoball® only. Both sets succeed in achieved neutral pH of 7 after the treatment. This indicates that mixed culture bacteria succeed in pH adjustment due to the bacteria act in dynamic population. 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 [20].

Table 2. COD Analysis

| Types and Analysis | Days | Mean (ppm) | Standard deviation |
|--------------------|------|------------|--------------------|
| Cosmoball® (COD Analysis) | 1    | 2000       | 14.14              |
|                    | 2    | 1880       | 28.28              |
|                    | 3    | 1800       | 21.21              |
|                    | 4    | 1750       | 28.28              |
|                    | 5    | 1710       | 21.21              |
|                    | 6    | 1700       | 21.21              |
|                    | 7    | 1700       | 21.21              |
| Types and Analysis               | Days | Mean (ntu) | Standard deviation |
|---------------------------------|------|------------|--------------------|
| Cosmoball® (Turbidity Analysis) | 1    | 90         | 0                  |
|                                 | 2    | 82         | 1.41               |
|                                 | 3    | 65         | 2.82               |
|                                 | 4    | 34         | 1.41               |
|                                 | 5    | 30         | 0                  |
|                                 | 6    | 25         | 1.41               |
|                                 | 7    | 17         | 0                  |
| Cosmoball® with Carrier A       | 1    | 88         | 2.82               |
| (Turbidity Analysis)            | 2    | 58         | 0                  |
|                                 | 3    | 23         | 4.24               |
|                                 | 4    | 24         | 2.82               |
|                                 | 5    | 23         | 0                  |
|                                 | 6    | 17         | 2.82               |
|                                 | 7    | 9          | 1.41               |

**Table 3. Turbidity Analysis**

**Figure 3. Percentage COD Reduction**

**Figure 4. Percentage Turbidity Reduction**
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 has been proven to be the best condition for efficient treatment of oleochemical wastewater.

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