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Performance of sequencing batch reactor for the removal of chemical oxygen demand from waste cooking oil

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ABSTRACT

The production of highly polluted waste cooking oil (WCO) that contains both inorganic and organic compounds has been increased in Malaysia particularly in food industries. This study was aimed to utilize a sequencing batch reactor (SBR) in order to investigate the aerobic treatment of WCO. The system was operated at pH ranging from 4 to 5 and temperature ranged from 25°C to 31°C. The SBR reactor was fabricated using Perspex with a working volume of 2 L. Experiments were conducted daily at fill, react, settle, draw, and idle phase at 1, 1, 2, 1, and 1 h, respectively. The chemical oxygen demand (COD) and turbidity were assessed in determining SBR performance. Highest COD removal and turbidity values were at 67% and 0.94 NTU, respectively. A stable effluent quality was achieved after 13 d of operational investigation. In general, the SBR treatment was able to achieve acceptable discharge limit for the final treated effluent.

Keywords: Waste cooking oil; Chemical oxygen demand; Sequencing batch reactor

1. Introduction

Approximately, 34.2 million L of waste cooking oil (WCO) is generated globally. The highest producer of WCO is the United States with annual increment of 2% [1]. Composition of pure cooking oil is mainly triacylglycerols (>92%) and WCO is cooking oil that has been used, subsequently it contains other elements besides glycerol [2]. WCO is considered to be a cost effective source for the production of biodiesel and bio-based products because it can be obtained and recycled efficiently and economically [3]. Due to the expansion of cooking oil industry and high utilization of WCO, large quantity of grease, oil, and fat can be discharged to the environment [4,5]. Without a proper management, it can be possible to have negative impacts to the environment by polluting natural resources [6–13].

Lipid substances present in municipal wastewater contribute to approximately 30%–40% of chemical oxygen

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demand (COD) [6]. Lipid excess can lead to intense treatment load for the water treatment plant causing low efficiency of oil removal and presence of excess lipid in effluent can cause not only hypoxia to the stream but also hinders the growth and aerobic microorganisms, subsequently causes environmental catastrophe [14,15].

Extensive treatment approaches have been developed throughout the years to elevate their removal capability with the most commonly used method is biological treatment [16–25]. The obvious economic advantage of biological treatment over other treatment methods such as chemical treatment is the capital outflow and operating costs [26–31]. Some industries utilize conventional biological treatment system using aerobic aeration pond. Unfortunately, these conventional treatment requires large space area [32]. In order to reduce its space requirements, sequencing batch reactor (SBR) has been successfully employed as one of the effective methods in biological treatment.

Sequence in SBR means phase which occurs within the same reactor (fill, aerate, settle and decant) [33]. SBR is a transformation of the continuous existence of activated sludge system into a batch system and it integrates various process in one chamber as well as it is far more flexible compared to conventional activated sludge. The design of SBR was simple, inexpensive, and capable of producing highly complied quality effluent [32,34]. As SBR method can be effectively automated in a very short aeration time, it is known to save more than 60% of the operating costs required for a conventional activated sludge system to achieve high effluent quality [34,35].

Many studies have investigated the conversion of WCO to biodiesel via several approaches [3,36,37]. Study by Chan et al. [32] found that SBR was proven to effectively treat palm oil refinery effluent. However, studies focusing on the removal of WCO from wastewater are very limited. Therefore, this study aims to investigate the removal of COD in WCO by using SBR.

2. Materials and method

2.1. SBR design

Cylindrical Perspex was employed to nurture formation of sludge granules collected from rubber industry with the reactor design of 0.05 m in parameter. In order to construct condition of an aerobic inside the reactor, the Perspex reactors were aerated thoroughly by air diffuser positioned at the bottom of the reactor purposely to generate smaller air bubbles. The Perspex reactor was designed with the maximum volume of 1 L. Wastewater spiked with WCO was continuously supplied into the laboratory scale SBR. A known concentration of disperse dye of 20 ppm was utilized. Sludge collected from Shorubber Sdn. Bhd. is employed in the reactor with the ratio of feed volume (V_f) to remaining volume (V_o) is 1:1. In addition, 500 mL of wastewater spiked with 20 ppm of WCO was provided into the reactors via "Fill" sequence with the application of dosing pump. At the same time, diffuser helps to assist the fixation of wastewater together with the sludge by aeration controlled by the installed aeration pump located at the bottom part of the reactor. In order to achieve an optimum aeration, a gas flow meter was installed in between the aeration pump and diffuser. The formation of fine bubbles was produced by a diffuser constructed from a porous structure stone. The reactor sequential operation was controlled automatically by applying timers. During the experiment, the temperature of reactors was continuously monitored to be at room temperature at 28°C ± 20°C. Experimental investigation was designed to accomplish within 6 h as a complete cycling time.

2.2. Reactor performance

The experiment was conducted to evaluate several parameters such as turbidity, chemical oxygen demand (COD), potential of hydrogen (pH), sludge velocity (SV), and temperature. The COD and sludge volume index (SVI) after 30 min were determined according to the methodology described in the American Public Health Association (APHA). In addition, certain operational parameters, such as temperature, pH and dissolved oxygen (DO) were measured using HACH and HANNA instrument, respectively.

3. Results and discussion

3.1. COD performance

The COD concentration and turbidity were observed throughout the experiment. As shown in Fig. 1, the highest COD removal can be observed at 96% which is on day 4. As a comparison, the lowest is on day 17 which is only 52% of COD removal. COD is not toxic to aquatic animals but high COD concentrations in the effluent can lead to low concentration of dissolved oxygen, subsequently affects aquatic animals [38].

Overall, the COD concentration fluctuated throughout the experiment and the COD removal started to stabilize after day 20. The fluctuating of COD concentration from day 1 to day 13 was mainly due to "Lag" phase. This phase is due to the physiological adaptation of the cells to the new environment which commonly occurs in industrial wastewater. An acclimation phase was essential to progressively introduce the community of microbial towards toxic organic or inhibitory compounds which may evolve from time to time in order to adapt new environment [32,39]. Study by Xu et al. [40] reported that the acclimation period can be achieved within 2–3 months.

3.2. Turbidity performance

The profile for turbidity concentration is closely associated with COD trend as shown in Fig. 1. The turbidity profile in Fig. 2 generally depicted the gradual increment of turbidity at early stage of SBR. Turbidity removal was exceptionally low from day 1 to day 9. Acclimatization occurs at an early stage of SBR, thus causing low suspended solids removal from the reactor [41]. In addition, the turbidity trend depicted declining till day 13. Turbidity concentration increased at day 14, 16 to 19, and at day 23. The presence of slight fluctuation on these days is may be due to the sludge that was thrust upward and attached to the cylindrical wall and the plastic cap of the reactor by bubbles created from aeration.

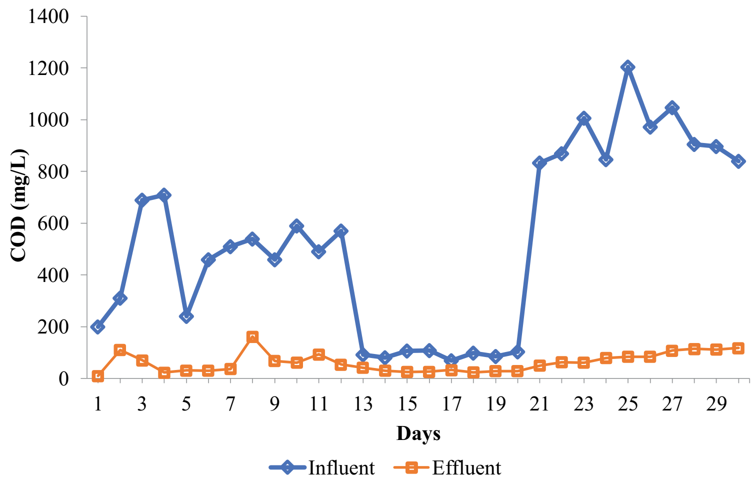

Fig. 1. COD concentration (mg/L) of wastewater effluent and influent.

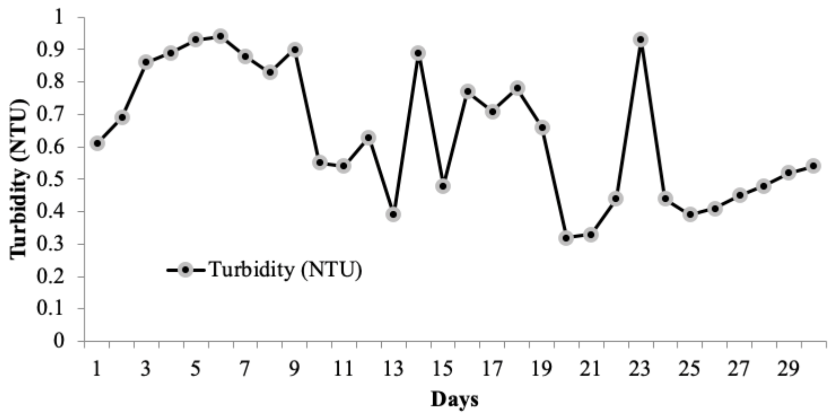

Fig. 2. Turbidity profile at the effluent (after treatment).

Study by Chan et al. [32] found that poor bacteria floc development in the reactor may also lead to the dispersion of suspended solids which can cause the increment profile in Fig. 2. At this stage, fraction of the bacterial population may washout causing high turbidity concentration and another fraction can reside in SBR hence the reduction in bacterial population, subsequently causing turbid effluent [39]. The turbidity value after day 24 remained stable afterwards and this is mainly due to adaptation of bacterial population to the new environment in SBR. This observation was also supported by Kang and Yuan [42] who reported the same trend with the acclimation phase causes fluctuating profile until the bacterial population are accustomed to the new surroundings. In general, the turbidity value for SBR was observed within the range of 0.32 to 0.94 NTU as shown in Fig. 2.

4. Conclusions

Investigation of factors affecting the performances of SBR for the COD removal in WCO was conducted. SBR was found to be successfully and effective method in the treatment of WCO, as it accomplished considerably reasonable concentration of COD removal. The removal efficiencies of COD were within the range of 64%–96%. The findings from this study are beneficial to design SBR system on a pilot scale. Future study should focus on the investigation of the SBR system in full scale because the SBR system depicted successful and favorable alternative method for biological treatment in treating WCO wastewater.

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Conflicts of interest

The authors declare that there is no known competing financial interests or personal associations that could have seemed to influence the work stated in this paper.

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