Biological treatability study for refinery wastewater using bench scale sequencing batch reactor systems

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Abstract

A petroleum refinery facility discharge wastewater with average influent COD concentration of approximately 500-750 mg/L during the period of this study. Study on the treatability of the petroleum refinery effluent wastewater was conducted using bench scale biological sequencing batch reactor systems. Six sequencing batch reactors (SBR) each of 2L liquid volume were operated at a 24 hours cycle. The SBRs were operated in various anaerobically stirred and aerobic modes. The average COD removals percentages for the aerobic reactor, combined anaerobic-aerobic reactors and aerobic mixed with domestic wastewater were found to be approximately, 91%, 91%, and 88% respectively, with its final average effluent COD of 63 mg/L, 65 mg/L, and 44 mg/L, respectively.
Keywords: sequencing batch reactor, petroleum refinery wastewater, COD.

1 Introduction

Petroleum refining involves the transformation of crude oil into final useful products such as gasoline, gas oil, kerosene and jet fuel, and petrochemical feed stocks. The refined products are produced after a series of separation and treatment processes. After initial crude desalting and fractionation, several treatment and conversion processes are employed to reach the final blending stocks [1]. These activities involve consumption of huge amounts of water and will lead to the production of wastewater streams of which characteristics are very much dependent on the complexity and number of processes in a refinery

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plant [2]. Based on the environmental quality act, wastewater generated via refinery processes must be treated before discharge [3]. There are several treatment methods based on the type and concentrations of contaminants such as physical, chemical and biological processes [4]. Physical treatment methods for instance, separation and adsorption are associated with the disadvantage of toxic compounds generation. Chemical precipitation also results in production of excess sludge. In addition, both physical and chemical treatment methods need to be accompanied by post treatment processes which make the treatment process more costly. Unlike them, biological treatment methods are cost-effective as they do not require high dosages of chemical materials and sophisticated devices. It can also be considered environmental friendly as less sludge is produced. Many researchers have successfully used biological methods for treatment of refinery wastewater [5–8].

Treatment of refinery wastewater was carried out in this study for a refinery facility that was looking for an alternative wastewater treatment method to ensure that the company will meet the regulatory limit of effluent set by the environment quality act. Current treatment method is not fully capable to treat the wastewater presumably due to changes in the constituents. Currently the wastewater treatment system consists of an oxidation pond and a final polishing pond. It is also noted that the performance of the oxidation pond varied.

From previous biodegradability study results, it was shown that the wastewater from petroleum refinery was ultimately biodegradable both aerobically as well as anaerobically [9]. A treatability study was proposed to the refinery to treat the waste stream biologically using bench scale sequencing batch reactors (SBR).

The objective of this study was to investigate the biodegradability of refinery wastewater. The study was to evaluate the performance of organic degradation of the wastewater sources using sequencing batch reactors operated in the aerobic, anaerobic mode as well as co-treating with municipal wastewater.

2 Methodology

2.1 Experimental procedure

Four different parallel batch treatment configurations were used to treat the petroleum refinery wastewater (Table 2). All the treatment configurations were operated in sequencing batch mode at a 24 hours cycle. The four reactors, each of 2 L sample volume, equipped with a mechanical stirrer were operated in an SBR mode with a 24 hours cycle. A supply of compressed air was provided for reactors operated in the aerobic mode. One litre of activated sludge from a sewage treatment plant was used as the biomass in all the aerobic reactors in treating 2-L of the wastewater samples. Reactor 2 was operated in the anaerobic stirred mode treating raw refinery wastewater, and was seeded with anaerobic sludge obtained from anaerobic tank. For this reactor, aeration was not provided in the cycle.

The SBR feeding time, mixing period, settling and decanting was set at 30 minutes, 21 hours, 2 hours, and 30 minutes, respectively. Effluent from anaerobic reactor 2 that treats raw wastewater was fed into the aerobic reactor 3. The aerobic reactor 4 treats low strength refinery wastewater mixed with domestic wastewater. Reactors 1, 3 and 4 were operated in the aerobic mode. Feeding time, aeration period, settling and decanting was set at 30 minutes, 21 hours, 2 hours, and 30 minutes, respectively.

Two litres of wastewater was decanted at the end of the period. The reactors were then fed with fresh 2-L of wastewater for the next cycle. The decanted liquid at the end of the 24 hour cycle was then measured for chemical oxygen demand (COD).

Table 1: SBR treatability study.

Reactor	Treatment System	Operation Cycle (hrs)				
		Feeding	Mixing	Aeration	Settling	Decanting
1	Aerobic for raw wastewater	0.5	21		2	0.5
2	Anaerobic for raw wastewater	0.5	21	None	2	0.5
3	Aerobic treating Reactor 4 Effluent	0.5	21		2	0.5
4	Aerobic for raw wastewater (mixed with 50% of domestic wastewater)	0.5	21		2	0.5

2.2 Sampling of wastewater

The wastewater samples for the study were collected from the balancing tank in the refinery's wastewater treatment system that stored the refinery raw wastewater. pH of the wastewater was in the range of 6-7. Average COD concentration for raw wastewater was found to be approximately 712 mg/L.

3 Results and discussion

3.1 Overall result for SBR

In this study, Fig. 1 illustrates the COD concentration (mg/L) at the end of each cycle vs days of SBR operation for the degradation of refinery raw wastewater operated under the aerobic and anaerobic mode.

Fig. 2 illustrates COD removal percentage at the end of every SBR cycle vs days for raw wastewater operated under the aerobic and anaerobic mode.

It can be observed that treatment of refinery raw wastewater using anaerobic SBR treatment achieved COD removal in the range of 30-40% at the end of the study period. However, treatment of refinery raw wastewater using aerobic SBR treatment achieved COD removals in the range of 80-90% after the third cycle.

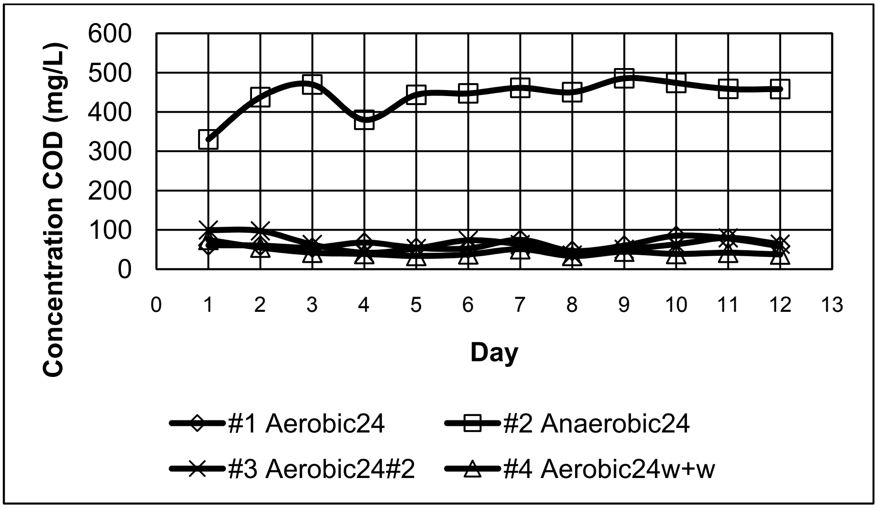

Figure 1: COD concentration vs sampling days for aerobic and anaerobic SBR treatment for raw wastewater.

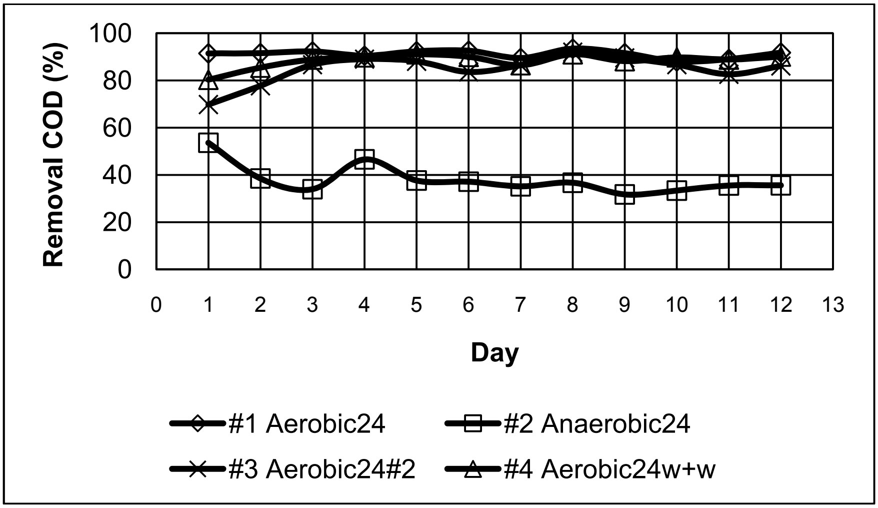

Figure 2: Removal COD percentage vs sampling days for aerobic and anaerobic SBR treatment for raw wastewater.

3.2 Result for aerobic SBR

From Fig. 3, it can be observed that the aerobic SBR reactor #3 that treats low strength refinery wastewater at a 24 hours cycle gave an average effluent COD concentration of 63 mg/L. Influent COD concentration was 712 mg/L. From Figure 3, it can be observed that this treatment gave an average COD removal of 91% throughout the study.

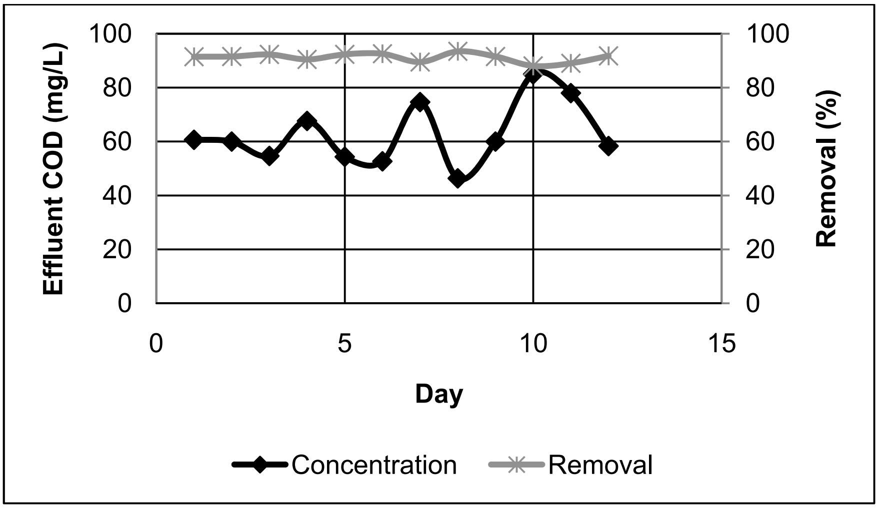

Figure 3: COD removals vs sampling days for SBR aerobic treatment for raw wastewater.

3.3 Results for anaerobic-aerobic SBR

The anaerobic SBR reactor #2 that treats refinery raw wastewater with a 24 hours cycle gave an average effluent COD concentration 441 mg/L (Fig. 4). Influent COD concentration was 712 mg/L. It can be observed that an average COD removal of approximately 40% was achieved throughout the study period.

Effluent from the anaerobic SBR reactor #2 was fed to be further treated in aerobic SBR reactor #3 with 24 hours cycle. This enhanced the final effluent treatment as shown in Fig. 5. Influent COD concentration was approximately 441 mg/L. Average effluent COD concentration was found to be approximately 65 mg/L with average COD removal of 85%. The overall average COD removal of this combined treatment was found to be approximately 91% throughout the study period.

3.4 Results for aerobic (mixed ww) SBR

Another treatment approach conducted was to operate an aerobic SBR reactor #4 that was fed with refinery raw wastewater combined with domestic wastewater.

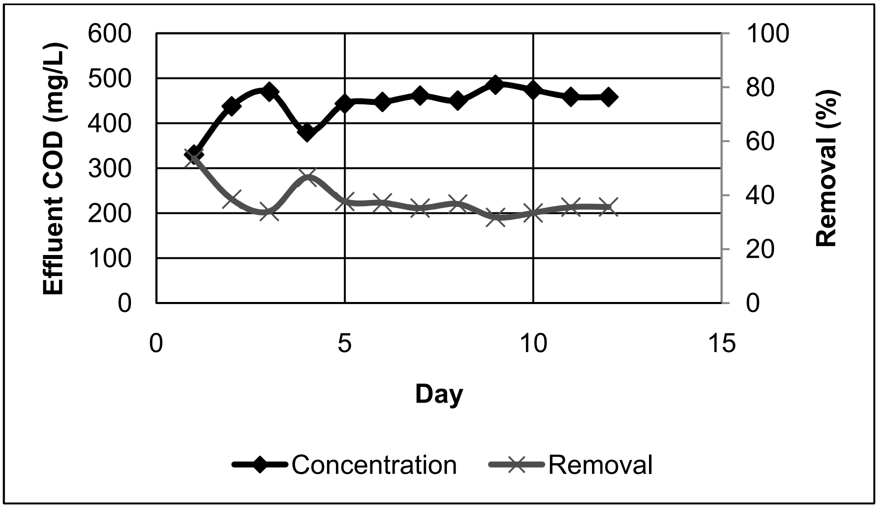

Figure 4: COD removals vs sampling days for SBR anaerobic treatment for raw wastewater.

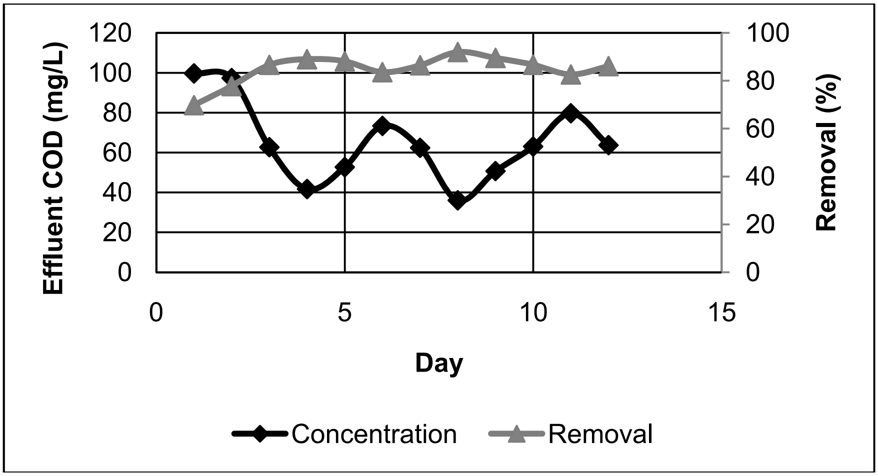

Figure 5: COD removals vs sampling days for SBR aerobic treatment for anaerobic wastewater effluent.

The results are shown in Fig. 6. Influent COD concentration was found to be approximately 378 mg/L after mixed with domestic wastewater which causes a dilution for the raw wastewater initial concentration and the average effluent COD concentration was found to be approximately 44 mg/L with an average COD removal of 88% throughout the study period.

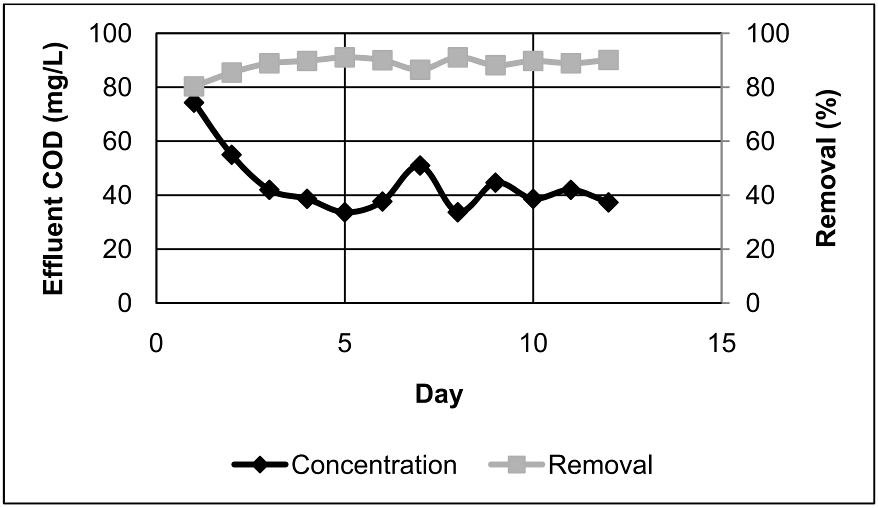

Figure 6: COD removals vs sampling days for SBR aerobic treatment for raw wastewater mixed with domestic wastewater.

3.5 Comparatives results for SBR systems

Fig. 7 shows that the results for aerobic reactor, combined anaerobic-aerobic reactors and aerobic mixed with domestic wastewater operated over cycle period of 24 hours, 48 hours, and 24 hours, respectively.

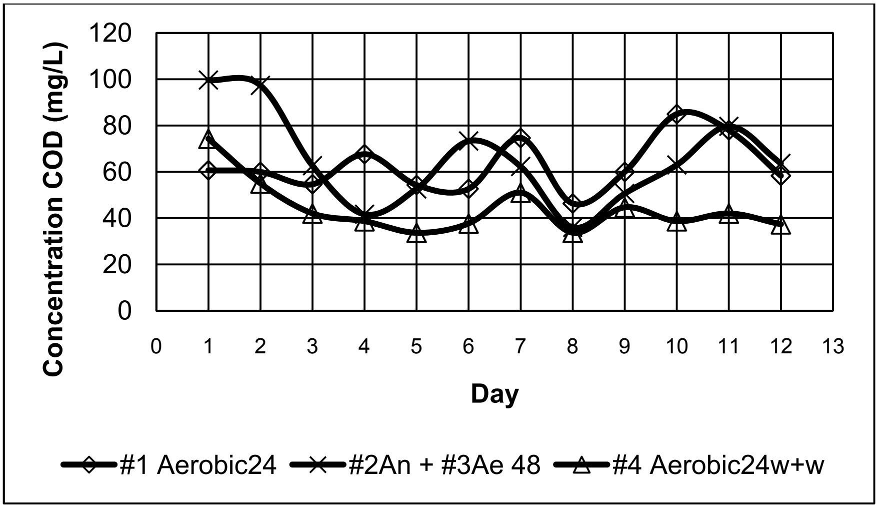

Figure 7: COD concentration vs days for SBR systems treating raw wastewater.

The average COD removals for the aerobic reactor, combined anaerobic-aerobic reactors and aerobic mixed with domestic wastewater achieved were found to be approximately, 91%, 91%, and 88% respectively, with its final average effluent COD of 63 mg/L, 65 mg/L, and 44 mg/L, respectively.

4 Conclusion

The sequencing batch reactor results show that the desired treatment level for raw wastewater can be achieved. Aerobic SBR reactors reported effluent COD concentration below standard B set by EQA 1974. Highest percentage COD removals were reported in the aerobic system and also in the combined anaerobic-aerobic system. The total cycle for aerobic reactor and the combined system was 24 hours and 48 hours, respectively. Lowest effluent COD concentration was recorded in the aerobic reactor when the wastewater was treated together with domestic wastewater, but the influent was already diluted because of the mixing. Nutrients provided by the domestic wastewater further enhance the treatment. However, further study need to be conducted on the nutritional requirements for the biological study.

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