Petroleum Refinery Effluent Biodegradation in Sequencing Batch Reactor

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Abstract

Petroleum refineries are looking for an alternative wastewater treatment method to ensure that they will meet the regulatory limit of effluent discharge standard set in environmental quality regulations. In this study, the overall goal was to monitor the treatment efficiency by a lab scale process in order to determine the degradation process in a batch biological treatment system. Three different configuration of sequencing batch reactor were used to treat petroleum refinery wastewater (PRWW). Aerobic SBR for raw PRWW, two-stage anaerobic-aerobic SBR for raw PRWW, and aerobic for mixed raw PRWW and domestic wastewater. The process was operated continuously in batch mode with continuous operation and monitoring with regards to COD, Ammonia-nitrogen, Nitrate-nitrogen, Phosphorous, Sulfate, MLSS, MLVSS. The effluent sCOD, Ammonia-nitrogen, Nitrate-nitrogen, TSS, and VSS for aerobic SBR were 54 mg/L, 5.9 mg/L, 1.47 mg/L, 66 mg/L, and 19 mg/L respectively. And for two-stage anaerobic-aerobic SBR were 49 mg/L, 0.8 mg/L, 3.1 mg/L, 60 mg/L, and 17 mg/L respectively. And for the aerobic SBR treating mixed PRWW with domestic were 53 mg/L, 0.8 mg/L, 1.9 mg/L, 76 mg/L, and 52 mg/L respectively. As a result, combined anaerobic-aerobic SBR treating PRWW gave pathway for maximum biodegradation and showed relatively better performance.

Keywords: Petroleum refinery wastewater, biodegradation, anaerobic-aerobic, SBR.

1 Introduction

Large volumes of water are used during the refining process in petroleum refineries which subsequently generate large volume of wastewater. The refinery wastewaters mostly contain high level of pollutants which are similar to those identified in crude oils [1]. Each refinery is made up of different plants, which produce different wastewater characteristics that is generally unique and can vary periodically [2]. Effluents discharged from petroleum refineries without proper treatment is hazardous to the environment. Studies have been shown that refinery effluent discharged into the water bodies resulted in the presence of high concentrations of pollutant in the water as well as in the sediments. The toxicants have been shown to be present in concentrations which may be toxic to aquatic organisms [3]. Biological treatment processes are known to be economical and an efficient method that can be used for treating wastewater from the refineries [4]. Petroleum refinery effluent treatment attracted researchers to provide reliable biological treatment process. Petroleum refinery wastewater and its major components such as phenols and BTEX has been studied to investigate the treatment efficiency by using aerobic, anaerobic and anoxic or a combinations of two or more biological conditions [5, 6, 7, 8].

The biodegradability of a local refinery wastewater was studied and it was found that the PRWW was ultimately biodegradable in a mixture with mineral nutrients and sludge in a single batch run for 28 days [9]. It was found that treatment of petroleum refinery wastewater can be achieved by using three different SBR configurations (aerobic SBR treating PRWW, anaerobic-aerobic SBR treating PRWW, and aerobic SBR treating mixed PRWW and domestic wastewater) [10]. In this study, the performance of SBR was studied in single cycle.

2 Methodology

Raw sample of the refinery wastewater was collected from a refinery facility and stored in a cold storage room perior feeding to the treatment system. Four different parallel reactors R1, R2, R3, & R4 were operated as sequencing batch reactor (SBR) systems in treating the petroleum refinery wastewater. The mode and cycle of operation of the reactors are described as in Table 1. All the four 3-L reactors with a 2-L sample were each equipped with a mechanical stirrer. All four SBR were operated at a 24 hour cycle. A supply of compressed air was provided for the reactors operated in the aerobic mode. One liter of biomass sludge was used as the seed in all the reactors in the start-up which lasts for three weeks.

Table 1: SBR configuration

No.	Mode	Influent	Operation Cycle (hrs)				
			Feed	Mix	Aerate	Settle	Decant
R1	Aerobic	PRWW	0.5	21		2	0.5
R2	Anaerobic	PRWW	0.5	21	NA	2	0.5
R3	Aerobic	R2 effluent	0.5	21		2	0.5
R4	Aerobic	PRWW+Domestic	0.5	21		2	0.5

Aerobic reactor R1 was fed with raw PRWW. In reactor R2 was operated in the anaerobic mode with the feeding time, mixing period, settling and decanting were set at 30 minutes, 21 hours, 2 hours, and 30 minutes, respectively. Effluent from R2 was then fed into the R3 which was operated in the aerobic mode. In reactor R4, the refinery wastewater was co-treated with domestic wastewater at a ratio of 1:1.

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 liters of wastewater was decanted at the end of the period. The reactors were then fed with raw wastewater for the next cycle. The schematic diagram of the SBR experimental set-up showed in Figure 1.

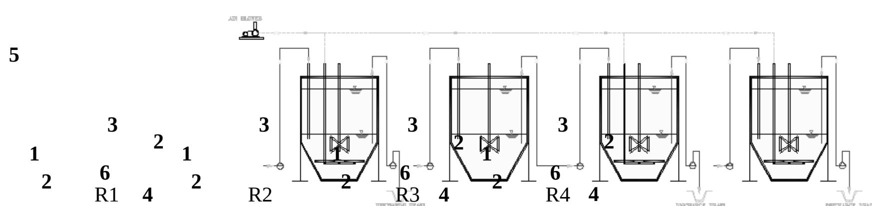

Figure 1: Schematic diagram of the SBR experimental set-up

(1. Influent point, 2. peristaltic pump, 3. Mechanical stirrer, 4. treated effluent, 5. air pump, 6. diffuser).

Parameters measurements were performed in triplicate, and were conducted in accordance with standard methods [11]. Samples were collected from the reactor while it was agitated, and measured for MLSS and MLVSS. Filtered sample (0.45µm) was measured for sCOD (soluble COD), Ammonia-nitrogen and Nitrate-nitrogen.

3 Results

The average characteristics of the raw petroleum refinery wastewater and the petroleum refinery wastewater mixed with domestic wastewater are tabulated in Table 2.

Table 2: Characteristics of PRWW and PRWW mixed with domestic w/w

No.	Parameter	Unit	PRWW	PRWW + domestic w/w
1	pH	-	6	6.5
2	COD	mg/L	1066	770
3	Ammonia-nitrogen	mg/L	7.8	9.9
4	Nitrate-nitrogen	mg/L	0.47	0.23
5	Sulfate	mg/L	22.6	28.4
6	Phosphorous	mg/L	5	6.8
7	TSS	mg/L	189.9	199.3

3.1 Aerobic degradation of PRWW

The aerobic degradation of PRWW in reactor R1 was plotted in Figure 2. It can be observed that the biomass concentration in the beginning of the cycle was above 3000 mg MLVSS/L but continues to decline towards end of the cycle to 2000 mg MLVSS/L. It can be observed that there was an immediate degradation of ammonia-nitrogen up to 8 hours. This may be due to the degradation of ammonia-nitrogen present in the raw wastewater. However, after 8 hours, the ammonia-nitrogen increased to x mg/L at the end of the cycle. This may be due to the degradation of biomass through the cycle as the biomass concentration seemed to decrease gradually from 4000 mg/L to y mg/L at the end of the cycle.

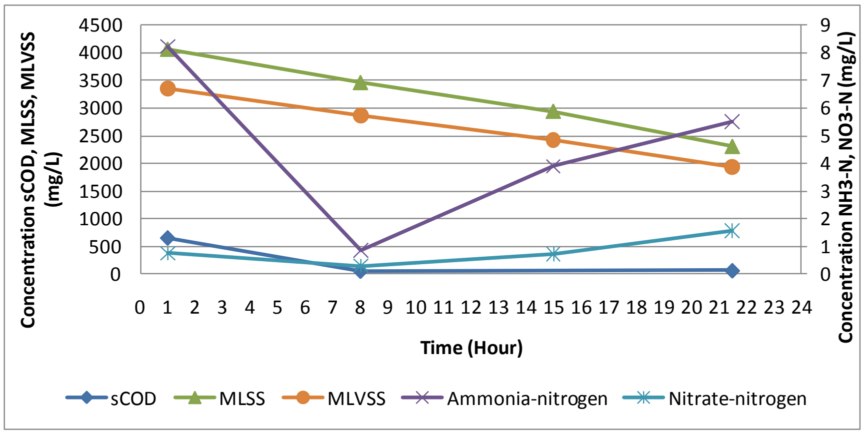

Figure 2: sCOD, MLSS, MLVSS, Ammonia-nitrogen and Nitrate-nitrogen concentration vs time for aerobic SBR R1.

3.2 Anaerobic degradation of PRWW

In anaerobic reactor R2, the biomass concentration in the beginning of the cycle was above 1000 mg/L and continued to increase towards the end of the cycle to 1300 mg/L as shown in Figure 3. The sCOD degradation was gradually removed over the 24-hr period. However, the ammonification of organic nitrogen during the anaerobic digestion elevated the ammonia-nitrogen.

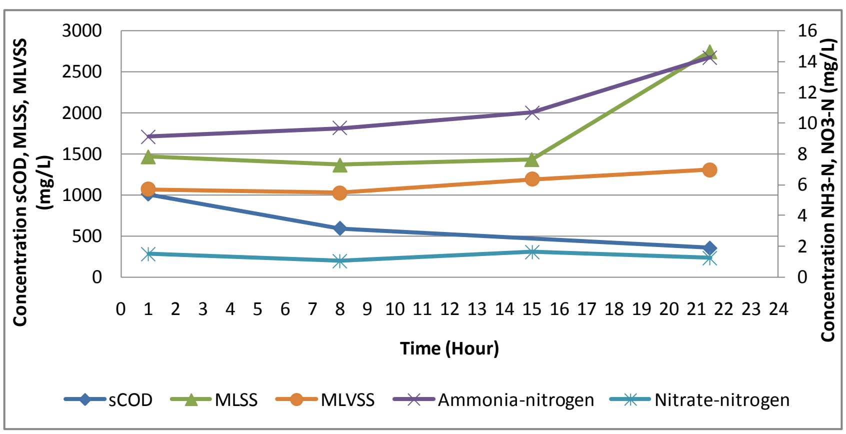

Figure 3: sCOD, MLSS, MLVSS, Ammonia-nitrogen and Nitrate-nitrogen concentration vs time for anaerobic SBR R2.

3.3 Aerobic degradation of anaerobic effluent

Effluent decanted from the anaerobic reactor R2 was further treated aerobically in reactor R3. Figure 4 showed that most of the sCOD was degraded during the first eight hours of aeration. The ammonia-nitrogen concentration was initially high as the effluent was taken from the anaerobic reactor. However, the ammonia-nitrogen is fast degraded into nitrate-nitrogen in the first eight hours of aeration. It can be seen that the nitrate-nitrogen concentration also increased gradually during the first eight hours of aeration. The nitrate-nitrogen concentration continued to increase towards the end of the study, indicating that sCOD removed produced ammonia-nitrogen which was then degraded into nitrate-nitrogen during the nitrification process.

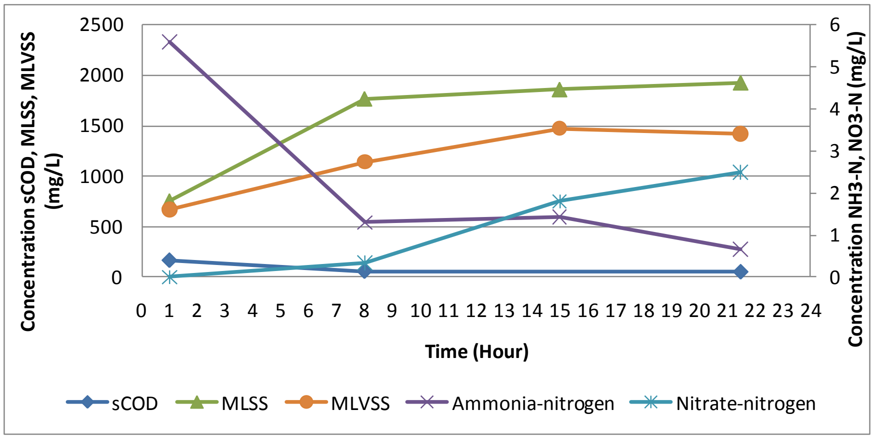

Figure 4: sCOD, MLSS, MLVSS, Ammonia-nitrogen and Nitrate-nitrogen concentration vs time for aerobic SBR R3.

3.4 Aerobic degradation of PRWW mixed with domestic wastewater

The PRWW was co-treated with domestic wastewater in reactor R4. It can be observed from Figure 5 that sCOD was removed consistently throughout the study period with the MLVSS was consistently maintained at 2300 mg/L. It can be observed that the initial ammonia-nitrogen concentration was degraded during the first 8 hours of aeration with the nitrate-nitrogen concentration increasing after the 8 hours.

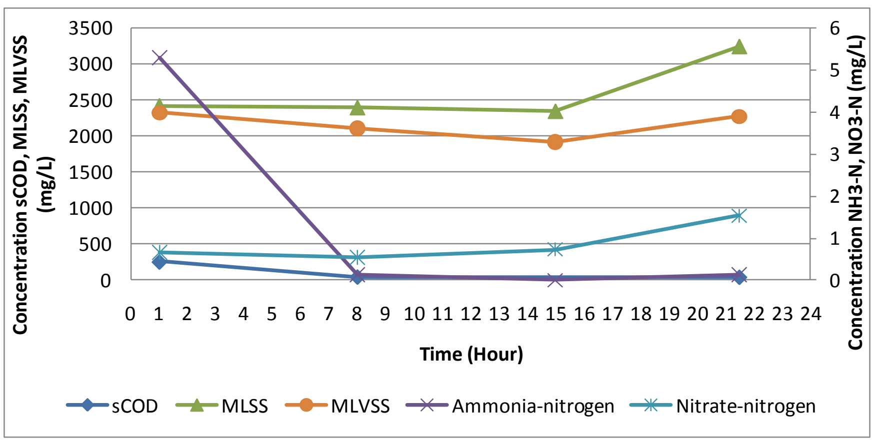

Figure 5: sCOD, MLSS, MLVSS, Ammonia-nitrogen and Nitrate-nitrogen concentration vs time for aerobic SBR R4.

Figure 6 showed that all three aerobic SBR configurations showed similar removal efficiency with regards to sCOD at the end of the cycle when the sample were taken from the decanted supernatant.

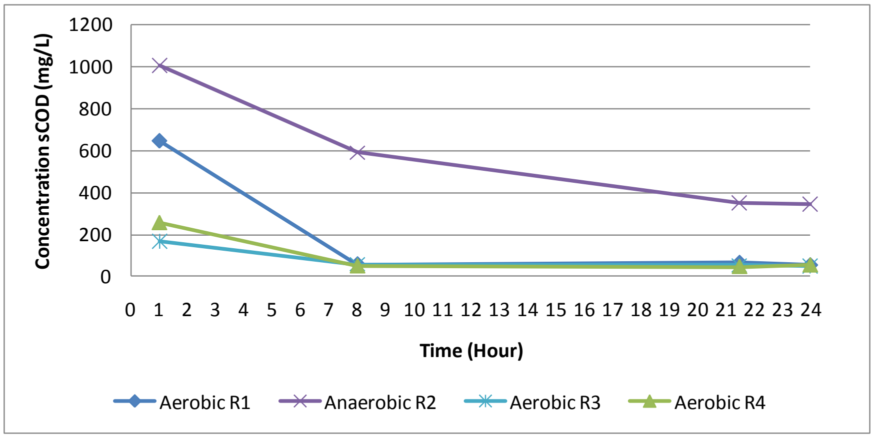

Figure 6: sCOD concentration vs time for SBR reactors R1, R2, R3 and R4.

4 Conclusion

All three aerobic reactors showed sCOD removal in the first 8 hours of aeration. This indicated that further refinement should be conducted with shorter aeration cycle. All the three SBR showed similar removal efficiency. Anaerobic-aerobic SBR may require longer cycle. Anaerobic-aerobic configurations gave overall highest removal efficiency and gave biological path for maximum biodegradation. Reactor R2 recorded lowest effluent concentration for sCOD, Ammonia-nitrogen, TSS and VSS. Further investigation needed with minimum sampling intervals and shorter SBR cycle for aerobic reactors and longer for anaerobic reactor.

Acknowledgment

This work was supported by the Universiti Teknologi PETRONAS graduate assistantship scheme.

5 References

[1] Sterling L. Burks, Review of pollutants in petroleum refinery wastewaters and effect upon aquatic organisms, Environment International, Volume 7, Issue 4, 1982, Pages 271-283, ISSN 0160-4120.

[2] Helen Wake, Oil refineries: a review of their ecological impacts on the aquatic environment, Estuarine, Coastal and Shelf Science, Volume 62, Issues 1-2, January 2005, Pages 131-140, ISSN 0272-7714.

[3] T.V. Otokunefor, C Obiukwu. (2005), Impact of refinery effluent on the physicochemical properties of a water body in the Niger delta. Applied ecology and environmental research 3(1): 61-72. ISSN 1589 1623.

[4] Jou, CJ.G. and G.C Huang, (2003), A pilot study for oil refinery wastewater treatment using a fixed film bioreactor. Adv. Environ. Res., 7: 463-469.

[5] Sami Sarfaraz, S. T. (2004). Anoxic Treatment of Phenolic Wastewater in Sequencing Batch Reactor. Water Research 38, 965–971.

[6] H.H.P. Fang, D.W. Liang, T. Zhang, Y. Liu, Anaerobic treatment of phenol in wastewater under thermophilic condition, Water Research, Volume 40, Issue 3, February 2006, Pages 427-434, ISSN 0043-1354.

[7] E.T. Yoong, A. P. (2001). Biodegradation of High Strength Phenolic Wastewater Using SBR. Wat.Sci.Tec. - Iwa , Vol 43 No 3 Pp 299–306.

[8] G. Ma, A. N. (2001). Creating Anoxic and Microaerobic Conditions in Sequencing Batch Reactors Treating Volatile BTX Compounds. Water Science and Technology - Iwa, Vol 43 No 3 Pp 275–282.

[9] Gasim H.A., S.R.M. Kutty, M.H. Isa, Biodegradability of Petroleum Refinery Wastewater in Batch Reactor, Proceeding of International Conference on Sustainable Building and Infrastructure (ICSBI 2010), Kuala Lumpur Malaysia. 2010.

[10] S.R.M. Kutty, Gasim H.A., P. F. Khamaruddin, A. Malakahmad, Biological Treatability Study for Refinery Wastewater using Bench Scale Sequencing Batch Reactor Systems, WIT Transactions on Ecology and the Environment, Water Resources Management VI, Vol 145, 2011 WIT Press, ISSN 1743-3541(online), pp 691-699. 2011.

[11] Clesceri, L. S., Eaton, A. D., Greenberg, A. E., Franson, M. A. H., American Public Health Association., American Water Works Association., & Water Environment Federation. (1996). Standard methods for the examination of water and wastewater: 19th edition supplement. Washington, DC: American Public Health Association.