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Feasibility of Development and Application of an Up-flow Anaerobic/Aerobic Fixed Bed Combined Reactor to Treat High Strength Wastewaters

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Abstract: Research was carried out in order to investigate the effect of the organic loading rate on the performance of an up-flow anaerobic/aerobic fixed-bed (UA/AFB) combined reactor. One bench scale UA/AFB combined reactor was constructed to investigate the treatment of high strength wastewater. Reactor was based on the combination of anaerobic and aerobic parts only in a single reactor. It was operated under four different runs in which organic loads were 0.8, 2.3, 4.7 and 7.6 kg COD/m^3 d, respectively. It was found that the total HRT 9 h (5 h as anaerobic and 4 h as aerobic) is long enough to obtain efficient removal of COD more than 95% at all of runs. Also, investigated reactor showed high ability to control organic loads. Based on the observed results, the use of UA/AFB reactor in practice seems to be a potential biotechnology for treatment of industrial wastewater contain high organic load.

Key words: High strength wastewater, fixed bed-combined reactor, organic load, anaerobic and aerobic treatment

INTRODUCTION

Current and impeding legislation for wastewater treatment discharge has necessity enhance treatment process capable of achieving high efficiency in removal of pollutants such as COD, nitrogen, phosphorous, suspended solids and pathogens[1-3]. Rapid industrialization has resulted in the generation of a large quantity of effluent with high organic contents, which if not treat poses the negative environmental impacts[4]. In recent years, considerable attention has been paid towards the development of compacted reactors for treatment of wastewater having high organic content[5]. One of the most new systems are submerged fixed bed reactors which developed during the last 15 years in which hydraulic current is either down-flow or up-flow[5,6]. Fixed Bed reactors offer the advantages of simplicity of construction, elimination of mechanical mixing, better stability at higher loading rate and capability to withstand large toxic and organic shock loads[4,7,8]. The most important limitation of these reactors is clogging of the bed due to increase in biofilm thickness and/or high suspended solid concentration in the influent[9,10]. Currently, several anaerobic and aerobic reactors in different pattern have been studied for treatment of high strength wastewaters. In this study, an up-flow anaerobic/aerobic fixed bed (UA/AFB) combined reactor was constructed and used to treat the wastewater containing high organic loads. Meanwhile, the anaerobic condition in the lower part of reactor was favorable to reduce a part of organic load that was vital for aerobic part of reactor and prevented the oxygen limited conditions in this part. Furthermore, the aerobic part could remove the residual of organic and produce an effluent with suitable quality to discharge.

MATERIALS AND METHODS

One bench scale up-flow anaerobic/aerobic fixed bed (UA/AFB) combined reactor was developed, constructed and operated during this study. The reactor consisted of a cylindrical plexy glass column with 13.5 cm in I.N Diameter, 100 cm in height and filled with PVC rings 1.5 cm in diameter as media with 800 m^3 m^{-2} in specific area (Fig. 1). The column was operated in an up flow mode that equipped with three sampling ports at different heights of the bed and consisted of two main parts: Lower anaerobic part with 6.2 in working volume and upper aerobic part with 7.8 L in working volume.

Synthetic wastewater used in this study prepared from dilution of the stock solution with tap water which its main characteristics are listed in Table 1. At the beginning

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Table 1: Characteristic of stock synthesized wastewater

Parameters	COD (mg L^{-1})	N (mg L^{-1})	P (mg L^{-1})	ALK (mg $CaCO_3$ L^{-1})	pH
Concentrations	10000	245.5	170	660	7.8

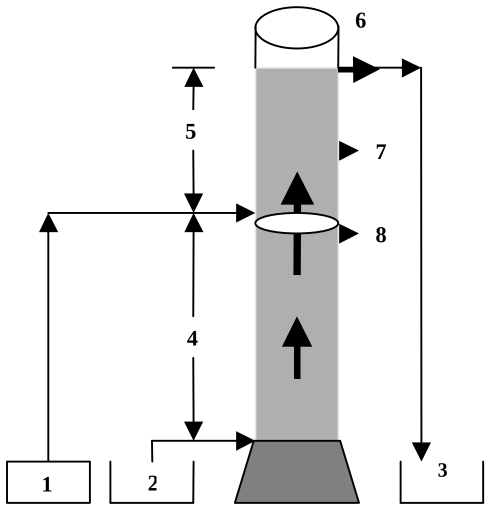

Fig. 1: Experimental setup of bench scale UA/AFB combined reactor (1-compressor, 2-influent, 3-effluent, 4-anaerobic part, 5-aerobic part, 6 ,7, 8 sampling ports)

of operation, reactor was inoculated with 2 L agriculture wastewater. After development of biofilm, reactor was operated in several organic loading based on changing organic content in stable influent flow rate. In any run, COD, phosphorus, ammonia nitrogen, Alkalinity, pH and DO, examined at inlet as well as sampling ports and analyses except nitrate were carried out according to the standard methods[11]. Nitrate was determined by DR 2000 Spectrophotometer.

RESULTS AND DISCUSSION

The main objective of this experiment was to define the ability of developed reactor to control of maximum organic load. Laboratory experiments were conducted at organic loading rates (OLR) 0.8, 2.3, 4.7 and 7.6 kg COD/m^3 d, respectively. The typical experimental runs of the reactor operation are characterized in Table 2.

The average parameters of samples gained from any sampling port under steady-state conditions and removal efficiency at any part of reactor are given in Table 3 and 4, respectively. The results showed that in loads of 0.8 , 2.3 and 4.7 kg COD/m^3 d, the anaerobic part of reactor was able to remove high percent of entering COD (>60%) and so reduce the organic loading on the aerobic

Table 2: Runs of operation at different OLR based on changing inlet COD in same HLR

Runs	Flow rates (L d^{-1})	HRT (h)	HLR (m d^{-1})	Inlet COD (mg L^{-1})	OLR (kg COD/m^3 d)
1	1.26	9	2.1	365	0.8
2	1.26	9	2.1	1050	2.3
3	1.26	9	2.1	2160	4.7
4	1.26	9	2.1	3500	7.6

HRT: Hydraulic retention time, HLR: Hydraulic loading rate, OLR: Organic loading rate

Table 3: Average COD concentrations at sampling ports in different runs

Port	1	2	3	4
Inlet	365	1050	2160	3500
1	121	315	799	2565
2	27	50	63	436
outlet	17	30	37	66

Table 4: COD removal efficiency at any part of reactor in different runs

Part	1	2	3	4
Total	95	97	98	98
Anaerobic	67	70	63	27
Aerobic (1)	78	84	92	83
Aerobic (2)	37	40	41	85

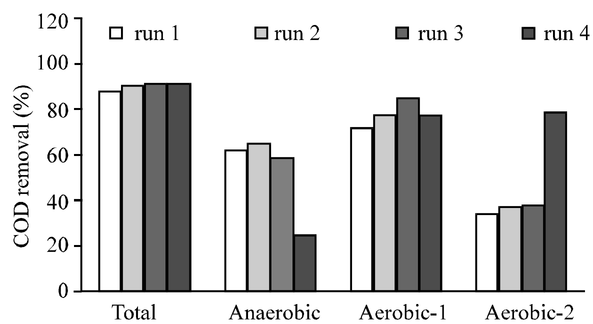

Fig. 2: Profile of COD removal efficiency in different part of reactor

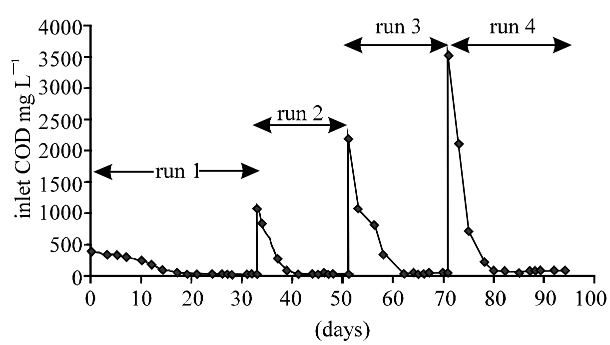

Fig. 3: Time requirement for reaching steady state at any loading rate

part, preventing oxygen limited condition in this part. In forth run that organic loading was 7.6 kg COD/m^3 d, because of high COD entering anaerobic section removed only 27% of COD, that is very lower in comparison of 1, 2 and 3 runs. This is due to this fact that higher organic cause to accumulate volatile fatty acids (VFA) at the anaerobic part of reactor, resulted in reduction of pH and so reduction of methanogen microorganisms, reducing removal efficiency in this part. Although, the aerobic part amended this decrease, so that the total of removal efficiency for COD amounted to 98%. Figure 2 compare the profile of COD removal efficiency in any part and total of reactor at any run. As it can indicate, total efficiency of reactor at any organic loading examined is more than 95%. The time required for establishing steady state conditions at any loading have been shown in Fig. 3.

The results show that the time required to reach steady condition in first run is longer than other runs in spite of inlet COD is low. Although the organic loading is higher, in runs 2, 3 and 4 because of enough biofilm on media, the steady state was reached at less than 7 days.

CONCLUSION

The up-flow anaerobic/aerobic fixed bed combined reactor were developed and tested with synthetic wastewater. A combined reactor can be very useful for the biological treatment of high strength industrial wastewaters especially in the case when space is a limiting factor. From analysis of obtained results, it could be concluded that the developed reactor is able to handle high organic loads. The total HRT around 9 h (5 h as anaerobic and 4 h as aerobic) is long enough to obtain efficient removal of COD up to secondary effluent standard limit with organic loads as high as 7.4 kg COD/m^3 d. Also, this reactor is able to handle organic shocks and can improve immediately after upsetting.

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