Efficiency Analysis of Anaerobic Baffled Reactor – by electrochemical Enhancement and Recirculation

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Abstract - *This work was aimed at investigating the performance of the anaerobic baffled reactor (ABR) for treatment of municipal wastewater at various hydraulic retention time (HRT). An effort was also made to improve the performance of ABR opting two strategies of effluent recirculation and electrochemical process integration.*
The experiment was carried out by making a small scale laboratory set up at the environmental engineering lab. Preliminary analysis of screened raw waste water is done and then treated using ABR. Tested sample was taken at different HRT, i.e 24 hr, 36hr, and 48 hrs and analyzed, this procedure is repeated by incorporating electrochemical system and again with recirculation. The project work showed maximum result for electrochemical enhancement of ABR than for exclusively ABR and ABR with recirculation. EABR showed 88% of BOD removal, 89% of COD removal and 72 % of turbidity removal.

Key Words: Anaerobic baffled reactor, recirculation, electrochemical enhancement, BOD, COD

1. INTRODUCTION

Anaerobic treatment of wastewater gained wide attention among researches and engineers, mainly sanitary engineers, mainly due to its economic merits over the conventional aerobic methods. The major advantages of anaerobic treatment are: (1) less energy requirement, as there is no need of aeration(2) reduces the cost of sludge management and disposal, as there is only low sludge(3) biogas production with high energy content, (4) low nutrients requirement, and (5) application of high organic loading and thus space saving.These feature posse the anaerobic process as a viable option for treatment of kitchen wastewater particularly in developing countries. A large number of full-scale anaerobic treatment plants using different anaerobic reactors including upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed with the satisfactory removal efficiencies have been built throughout the world. However, these technologies have not been well-adopted for the decentralized treatment of rural and urban sewage in the most of developing countries because they need complex maintenance and control, and skilled manufacturers and operators. Among the high rate anaerobic reactors, anaerobic baffled reactor (ABR) are promising for kitchen wastewater treatment in such a case. ABR is described as a series of UASB reactors in which the wastewater is forced to flow under and over of a series of the vertical baffles as it passes from the inlet to the outlet. The compartmentalization of the reactor prevents horizontally movement of the biomass and thus a high amount of active biomass retains in each compartment. Indeed the bacteria within the reactor tend to rise and settle with gas production in each compartment .This feature provides the excellent contact between the contaminants and the microorganisms, longer biomass retention times and better resilience to organic and hydraulic shock loadings .The main feature of ABR as compared to other highrate anaerobic reactors is its simplicity to design, construct and operate.

1.1 Objective of the study

This study was aimed at integrating the electrochemical process with the ABR for improving its performance in treating kitchen wastewater. At first, upon the start up of the ABR, its performance in treating the kitchen wastewater was evaluated at different hydraulic retention times (HRT). Then an electrochemical process was integrated with the ABR and the effect of various electrical densities was investigated on the enhancement of the ABR effluent quality

1.2 Scope of the study

Developing countries are facing problem regarding the reuse and recycle of waste water especially in rural areas. Conventional water treatment system are costly. Anaerobic baffled reactor is a good alternative for the water treatment in such areas. Anaerobic baffled reactor has many advantages over aerobic system. One of the major advantage is the production of biogas which can be used as a fuel. So anaerobic baffled reactor is sustainable and cost effective water treatment system

2. METHODOLOGY

A bench-scale ABR setup was fabricated from glass sheet and installed. The schematic of the setup is shown in Fig. 1. The ABR had L W H dimension of 60 x 27 x 30 cm consisting of 6 equal size chambers with the total working volume of 37 L. Each chamber had a working volume of 6.17 L. The ratio of up-comer to down-comer section of each compartment was 3:1. Top of the reactor was covered and a valve was installed to vent the biogas. The reactor was fed with the real domestic screened wastewater using a peristaltic pump.

In order to improve the performance of the ABR, it was integrated with an electrochemical system providing the

EABR (electrochemical system with ABR). The electrochemical system was composed of a pair of similar material (steel or aluminum) plate type electrode with the width and length of 2 and 25 cm, respectively, powered by a DC power supply. The thickness of the electrodes was 2 mm. In the EABR, the electrodes were inserted at the distance of 1 cm from each other in the 4th down-comer chamber of the reactor. The submerged length of each electrode was 15 cm. The DC electrical current at the given density was applied between the electrodes through the weirs connected to the power supply instrument.

Fig -1: ABR reactor set up fed with raw sludge

2.1 Startup of ABR

The reactor was initially fed with sludge collected from local anaerobic treatment plant. The sludge is fed up to 30% of the reactor volume, so the depth of sludge is 9 cm from bottom. The Anaerobic baffled reactor was started up with feeding raw waste water at an HRT of 48 hrs. BOD and COD removal of the samples were analyzed for startup period. The reactor attained steady state performance after 2 weeks of start up. Upon startup the reactor is fed with raw kitchen waste water for the analysis of performance at different HRT.

2.2 Performance of ABR

Initially performance of ABR was analyzed. To study it the experiment was conducted and examined at different HRT. The experiment is carried in 3 trials. Initially raw kitchen waste water is fed to the reactor and the parameters are checked initially and at different HRT. The processes are repeated in 3 trials to reduce the maximum probable error. The domestic kitchen waste water is fed to the reactor using a peristaltic pump. The sample is collected from the outlet provided at different chambers. The sample is taken at 24 hrs, 48 hrs and 72 hrs. After each sampling the collected sample is taken to the laboratory for detailed analysis of parameters.

Table 1 contains the values of different parameters of waste water initially and at different HRT. From the table we can observe various changes happening in different parameters pH tends to increase with increase in HRT whereas turbidity shows a gradual decrease. BOD and COD decreased noticeably with a maximum decrease at 48 hours HRT.TSS and TDS also decreased, but does not show any noticeable trend. Finally nitrate and phosphate also increases with increase in HRT. Nitrate increases in trace quantity and phosphate increases in a noticeable rate.

Table -1: Performance of ABR

PARAMETERS	INITIAL	DIFFERENT HRT		
		24 HRS	48 HRS	72 HRS
Ph	5	5.6	5.9	6
Conductivity (milli ohm/cm)	0.671	0.781	0.890	1.201
Turbidity (NTU)	88	40	48	36
TSS (mg/L)	500	250	210	278
TDS (mg/L)	387	400	417	520
BOD (mg/L)	106	28	25	29
COD (mg/L)	518	120	105	115
NO_3^- (mg/L)	0.2	0.9	1.2	1.8
PO_4^-(mg/L)	19	26	32	40

Chart-1 shows the variations of BOD, COD and Turbidity of ABR . BOD decreased from 106 mg/l to 28 mg/l at 28 hrs HRT then further decreased to 25 mg/l at 48 hrs HRT and further slightly increased to 29 mg/l at 72 hrs HRT. The COD concentration also decreased from 518 mg/l to 120 mg/l at 24 hrs HRT , further decreased to 105 mg/l at 48 hrs HRT and then a slight variation at 72 hrs HRT. The Turbidity shows a gradual decrease from 88 NTU to 40 NTU at 24 hrs,48 NTU at 48 hrs, and 36 NTU at 72 hrs HRT.

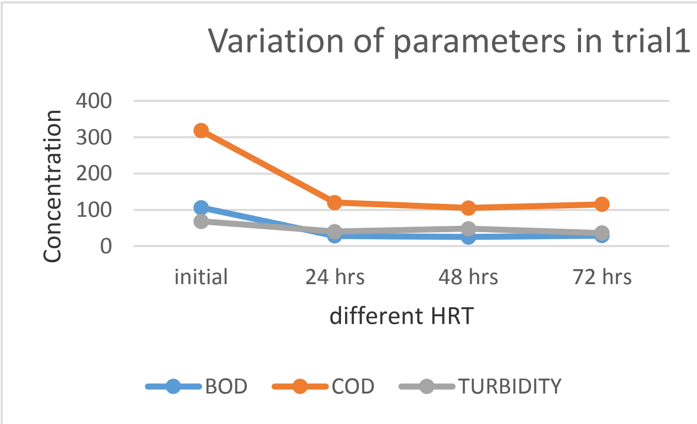

Chart-1 Variations of parameters in ABR

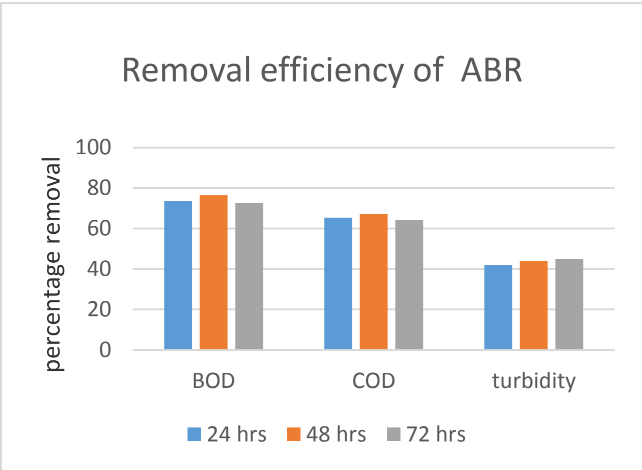

Chart-2 removal efficiency of ABR

Chart-2 shows the variations in removal efficiencies of BOD, COD and turbidity at different HRT. BOD shows 73.6%, 76.4%, and 72.6% for 24 hrs, 48 hrs and 72 hrs respectively. COD shows 65.4%,67% and64% respectively for 24 hrs, 48 hrs and 72 hrs respectively. Turbidity shows a removal efficiency of 42%,44% and 47% respectively for 24 hrs, 48 hrs and 72 hrs.

2.3 Performance of ABR with recirculation

A Performance of ABR was analyzed by providing recirculation to find to find whether recirculation enhances removal efficiency or not. in this project work, 30% recirculation was adopted, which means 30% of initially treated water was mixed with waste water before experiment and the procedure is carried out.

Table-2 Performance of ABR with recirculation

PARAMETERS	INITIAL	DIFFERENT HRT		
		24 HRS	48 HRS	72 HRS
pH	6.2	6.5	6.9	6.9
Conductivity (milli ohm/cm)	1.128	1.392	1.586	1.819
Turbidity (NTU)	96	38	30	31
TSS (mg/L)	281	268	254	250
TDS (mg/L)	596	419	410	450
BOD (mg/L)	210	46	42	44
COD (mg/L)	563	96	90	92
NO_3^- (mg/L)	4.8	5.2	5.3	5.4
PO_4^-(mg/L)	50	56	68	72

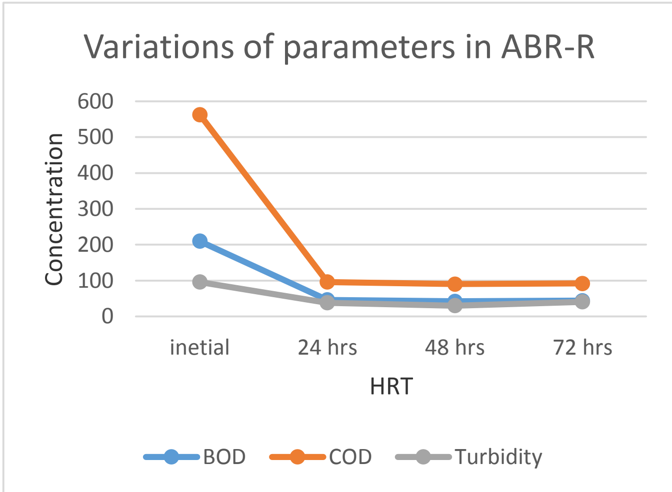

Chart-3 variation of parameters in ABR with recirculation

Chart-3 shows the variations of BOD, COD and Turbidity of ABR in trial 3. BOD decreased from 129 mg/l to 37 mg/l at 24 hrs HRT then further decreased to 32 mg/l at 48 hrs HRT and further slightly increased to 36 mg/l at 72 hrs HRT. The COD concentration also decreased from 386 mg/l to 76 mg/l at 24 hrs HRT, further decreased to 69 mg/l at 48 hrs HRT and then a slight variation, 72 mg/l at 72 hrs HRT. The Turbidity shows a gradual decrease from 78 NTU to 29 NTU at 24 hrs,27 NTU at 48 hrs, and 25 NTU at 72 hrs HRT.

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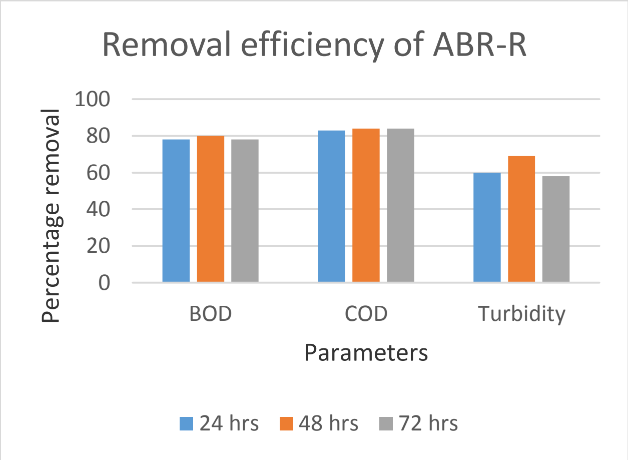

Chart-4 Removal efficiency of ABR with recirculation

Chart-4 shows the variations in removal efficiencies of BOD, COD and turbidity at different HRT of ABR-R.

2.4 Performance of EABR

In this work performance analysis of anaerobic baffled reactor is carried out by electrochemical enhancement. In this work, 2 steel electrodes are connected as anode and cathode from a 9 volt DC supply. The dimensions of the electrodes are 15 cm length, 2cm width and 2 mm thickness. The electrodes are placed between the 4th and 5th chamber of anaerobic baffled reactor. The performance is analyzed in three trial

Table-3 Performance of EABR

PARAMETERS	INITIAL	DIFFERENT HRT		
		24 HRS	48 HRS	72 HRS
pH	6	6.2	6.7	6.9
Conductivity (milli ohm/cm)	3.876	4.28	5.10	6.217
Turbidity (NTU)	120	30	28	32
TSS (mg/L)	280	250	210	190
TDS (mg/L)	420	410	400	380
BOD (mg/L)	188	28	21	23
COD (mg/L)	564	79	62	68
NO_3^- (mg/L)	2.8	4.6	5.2	6.9
PO_4^-(mg/L)	30	46	56	70

Table-3 contains the values of different parameters of waste water initially and at different HRT. from the table we can observe various changes happening in different parameters pH tends to increase with increase in HRT whereas turbidity shows a gradual decrease. BOD and COD decreased noticeably with a maximum decrease at 48 hours HRT.TSS and TDS also decreased, but does not show any noticeable trend. Finally nitrate and phosphate also increases with increase in HRT. Nitrate increases in trace quantity and phosphate increases in a noticeable rate.

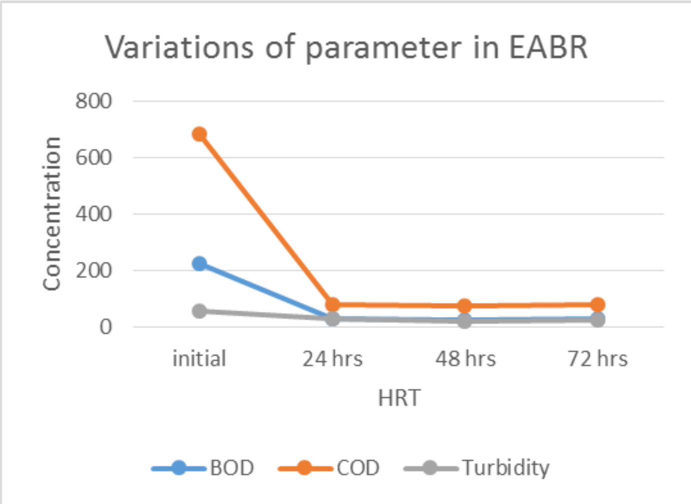

Chart-5 Variations of parameters in ABR

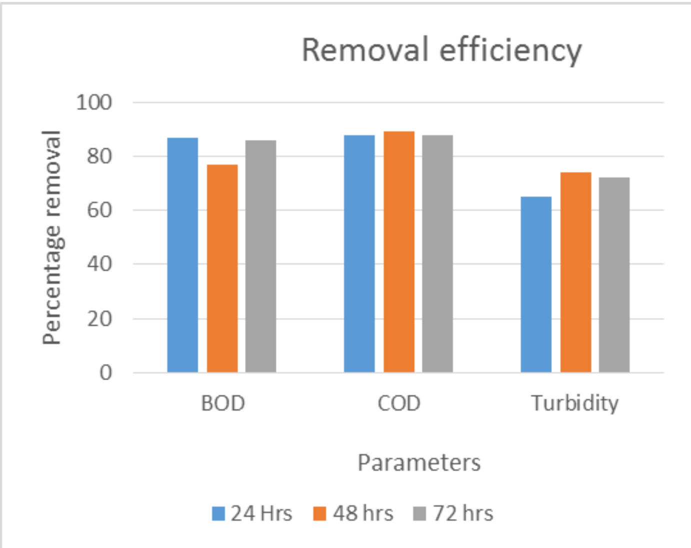

Chart-6 Removal efficiency of EABR

Chart-6 shows the variations in removal efficiencies of BOD, COD and turbidity at different HRT in EABR trial 1. BOD shows 86.7%, 88%, and 85.9% for 24 hrs, 48 hrs and 72 hrs respectively. COD shows 88%, 89% and 88% respectively for 24 hrs, 48 hrs and 72 hrs respectively. Turbidity shows a removal efficiency of 65%, 74% and 72% respectively for 24 hrs, 48 hrs and 72 hrs.

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3. CONCLUSIONS

The study of waste water treatment conducted using anaerobic baffled reactor and its modification to find its efficiency in treating kitchen waste water. Experiments were conducted in three trials, with different HRT to find at which HRT does ABR works more efficiently. Also, which modification is best for the treatment of kitchen waste water. In this work process, anaerobic baffled reactor is tested without any modification at different HRT, and further tested by incorporating recirculation and electrochemical enhancement. Recirculation was attained by mixing 30% of the treated waste water mixed with untreated wastewater and electrochemical enhancement was attained by providing 2 steel electrodes at the 4th and 5th chambers of anaerobic baffled reactor. The electrodes were connected to a 9V DC supply

From the result observed, it can be inferred that anaerobic baffled reactor is effective in treating waste water even in a small scale. It is observed that the pH tends to show an increase in all the trials. In exclusively ABR pH increased but the treated waste water maintain a slightly acidic nature. Conductivity increased, TDS and TSS showed a decrease. Nitrate and phosphate increased due to the metabolism of the microorganisms in the sludge. TDS and TSS decreased as the micro organism use up the solute and suspended particles and organic matter. As a result there is increase in nitrate and phosphate, microorganism use up this nutrients from the waste water for the metabolism. The BOD, COD and turbidity showed a considerable decrease. BOD removal efficiency of ABR is 76.2%, COD removal efficiency is 82% and turbidity removal efficiency is59%.

Similar pattern of observation can be inferred from ABR with recirculation and EABR. Recirculation does not show much variation compared to exclusively ABR, whereas EABR shows very effective removal of BOD, COD turbidity. The removal efficiency in ABR-R for BOD is 78%, COD 85%, turbidity is 65%.and for EABR, 88% of BOD removal, 89%of COD removal and 72%of turbidity removal is observed. From the experiment it can be concluded that EABR is very much effective in treating kitchen waste water. With appropriate turbidity and odour removal technology, the ABR can be used in a water treatment system in large scale as well as small scale. The ABR is very effective in treating low strength kitchen waste water.

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