

Treatment of high strength wastewater using anaerobic baffled reactor with media during the start up phase

Ahmed S.Khalil ¹, Medhat A.E. Moustafa ², Walid Elbakri ³

Abstract— Population growth and depletion of high quality fresh water supplies have led to an increased interest in wastewater reuse to augment potable water supplies either directly or indirectly so this paper presents a simple experimental set-up was used to study the treatability aspect of synthetic waste water. Three types of systems: i) conventional anaerobic baffled reactor (ABR (A)), ii) anaerobic baffled reactor with sponge bio-film (ABR (B)), iii) anaerobic baffled reactor with fiber bio-film (ABR (C)), were experimented under different COD (0-5000 mg/l) in the first steps, with flow rate 38 l/d and pH value 8.5. pH effect on treatability was also investigated. The main objective of this study was to investigate the behavior of three reactors and verify the use of bio-film in improving treatability, to promote theses the use of two types of bio-film sponge and fiber. Many significant factors were considered such as: temperatures, number of baffled in reactor, shape baffled and location of reactor to avoid lighting. For all tested reactors, influent COD concentration, influent pH, temperature in the reactor, effluent COD concentration, effluent pH and flow rate, in the start-up stage. Test results revealed the ABR C scenario gave the highest COD % removal comparing with the other two scenarios. Results showed that decreasing pH value had an adverse effect on treatment efficiency for all cases

Keywords — Anaerobic digestion, high strength wastewater treatment, anaerobic baffled reactor, sponge media, fiber media, and Chemical Oxygen Demand (COD).

I. Introduction

With the improvement of world economic condition, water resources are becoming increasingly deficient and the quality

1- Ahmed S.Khalil

Faculty of Engineering, University of Kafr Elsheikh,
Egypt

2 -Medhat A.E. Moustafa

Faculty of engineering, University of Alexandria.
Egypt.

3- Walid Elbakri

Faculty of engineering, University of Alexandria.
Egypt.

of environment in the world is constantly becoming worse in most regions. Treatment and disposal of wastewater is presently one of the serious environmental problem contributors. Therefore, there is a dire need to develop reliable technologies for wastewater treatment. Anaerobic process for wastewater treatment has attracted increasing attention. This process has advantages as design simplicity, use of non-sophisticated equipment, high treatment efficiency, low excess sludge production and low operating and capital cost [1], [2].

The high-rate anaerobic processes could be achieved by separation between the hydraulic retention time (HRT) and the solid retention time (SRT). In addition, stringent environmental legislation is giving the impetus to developing anaerobic wastewater treatment processes due to potential economic and environmental benefits they hold over traditional aerobic [3].

Nowadays, many researchers have focused on anaerobic reactors for the treatment of wastewater. As one of the high-rate anaerobic reactors, the ABR was extensively used in treating wastewater. The ABR was initially developed at Stanford University and it can be described as a series of up-flow anaerobic sludge blanket reactors (UASBs). As the name suggests, it consists of a series of vertical baffles to force the wastewater to flow under and over them as it passes from the inlet to the outlet. The wastewater can then come into intimate contact with a large amount of active biomass, while the effluent remains relatively free of biological solids [4], [5]. The significant advantage of the ABR is its ability to separate acid genesis and methanogens is longitudinally down the reactor [6], [7], [8]. This can permit different bacterial population to dominate each compartment, acidification predominating in the first compartment section and methanogens is dominant in the subsequent section [9].

The main objectives of this paper may be summarized as follows:-

- Study the treatability aspect of high range COD concentrated wastewater on three types of systems (conventional ABR, ABR with sponge bio-film and ABR with fiber bio-film).
- Conduct a comparison study between three types of systems.
- Study the stability of the PH value with existing biofilm.

II. Materials and Methods

A. Experimental program

The purpose of this research is to study the treatability of high range organic waste using Anaerobic Baffled Reactor (ABR). The proposed types of reactor systems as following:

- Conventional anaerobic baffled reactor [ABR (A)].
- Anaerobic baffled reactor with sponge as media [ABR (B)].
- Anaerobic baffled reactor with fiber as alternative media [ABR (C)].

The experimental tests were performed under different organic loading rate. Alkalinity effect on biomass was also investigated.

B. Design of reactors

- Dimension and shape

Three bench scale ABRs were carried out in parallel mode. ABR is constructed from 5mm thick transparent Perspex, with internal dimensions of 80 cms long, 25 cms width and depth of 50 cms with working volume of 76 l as shows schematic diagram of the reactor in "Fig 1".

The reactor is divided by vertical baffles into 5 compartments each one is 15.2 l volumes. The width of the up-comer is 12 cms and width of down comer is 4cms, the lower part of the down-comer baffles were angled at 45o in order to direct the flow evenly the up comer. Each compartment is equipped with sampling ports [10].

The effective treatment volume is that volume occupied by the sludge blanket and active biomass. An additional volume exists between the effective volume and the gas collection unit where some additional solids separation occurs and the biomass are diluting.

The designed nominal liquid volume of the reactor based on using an acceptable organic loading. The highest COD concentration equals 15,000 mg /l, O.L.R equal 8 kg COD/m³. d, and Q equal 1.58 l/h all this criteria from Metcalf & eddy [11].

$$V_n = Q S_o / L_{org} \quad (1)$$

Where:-

V_n = nominal (effective) liquid volume of the reactor, m³

Q = influent flow rate, m³/h

S_o = influent COD, kg COD/m³

L_{org} = organic loading rate, kg COD/m³.d

- Biomass

The experimental work was carried out by operating the activated sludge (AS) pilot plant to anaerobic sludge by anaerobic conditions in the reactor. Sludge were withdrawn from the collection tank after the settling tank for AS.

The 36 L of biomass was divided evenly between each of the five compartments within each reactor (i.e. 7.2 L

/compartment). The sludge contains MLSS = 25000 mg/l, and MLVSS = 19875 mg/l.

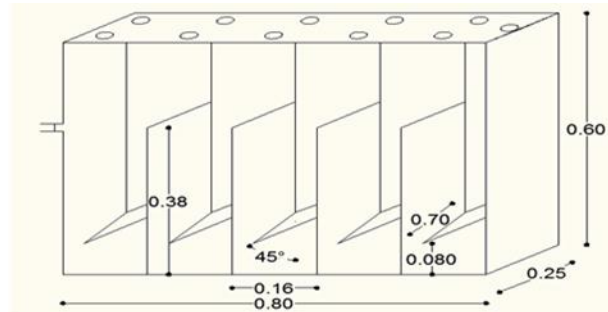


Figure1. Dimensions and shape of anaerobic baffled reactor (Note: all dimensions in m).

- Temperature

The reactor was operated under mesospheric condition maintained constant at 35°C [11], [12]. Keep the temperature by a temperature regulator (Heater) placed in each chambers.

- Properties of the media used

There are three types of reactors; the first is conventional reactor (A), while another two reactors contain different media (B), (C).

The required characteristics of the suitable bio-film carrier are as follows: large specific surface area, bio-affinity, stability, acid and base resistance, oxidation resistivity, hard to biodegrade and age, light mass and strong mechanical strength. In addition, the used carrier must be cheap enough for its practical application and has no toxic effect on cells, [13].

For the reactor (B) sponge media (Cuboids shape) amounted to 50mm in height 40mm in length 30mm in width. The sponge characteristic parameters were surface area (157 m²/m³), density (65 kg/m³), and voids ratio (0.65). The total amount of sponge added to the reactor was approximately 7.6 l equals to 10% of working volume, (that resulting of percentage from the orthogonal tests by [14]). Sponge placed in each chamber of the reactor in a trawl (reactor contain on five trawl from sponge), to facilitate the deal with it, and to ensure its stay in position. Each group from trawl fixed down the chamber by clips. "Fig 2" illustrates shape the sponge before and after treatment (A, B respectively).

The reactor (C) Fiber media (Almost ball shape because it is difficult to the formation exactly) amounted to 60mm in diameter. The fiber characteristic parameters were surface area (246 m²/m³), density (28 kg/m³), and voids ratio (0.8). The total amount of fiber added to the reactor was approximately 7.6 l equals to 10% of working volume, that resulting from the orthogonal tests by [14]. Fiber placed in each chamber of the reactor in a trawl (reactor contain on five trawl from fiber), to facilitate the deal with it, and to ensure its stay in the position. Each group from trawl fixed down the chamber by clips. "Fig 3" illustrates

shape the fiber before and after treatment (A, B respectively).



Figure 2, Shape of the sponge (A. Before treatment, B. After treatment).



Figure 3. Shape of the fiber (A. Before treatment, B. After treatment).

- Operation of the reactors

Synthetic wastewater was prepared daily, and put it in the feed tank that distributes synthetic wastewater to three constant head tanks. These tanks maintaining the hydraulic head and thus ensure evenly distribution of wastewater and a valve calibrating to control inflow discharge, as show in "Fig 4". Use the constant head tanks with system instead of peristaltic pump to avoid power outage.

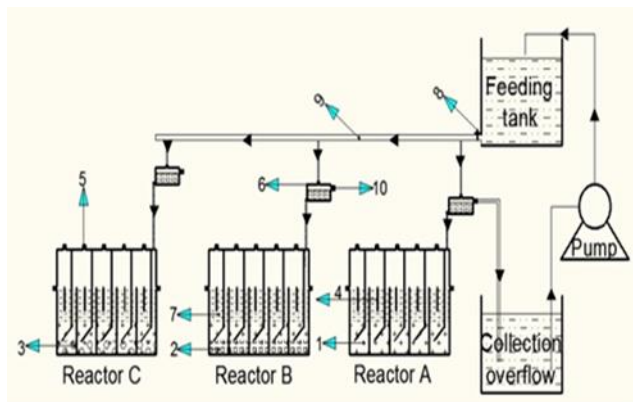


Figure4. Installation of the system and method of feeding. (1) Sludge = 1/2 Vw, (2) Sponge media, (3) fiber media, (4) temperature regulator, (5) sample port, (6) constant head tank, (7) Synthetic wastewater, (8) valve, (9) Pipeline connecting, (10) overflow

Activated sludge system was seeded with activated sludge from sequencing batch reactor treatment plant (SidySalm-Egypt- wastewater treatment plant). During the startup, steady state, shock load, and return to steady state periods. The units were fed with synthetic sewage. The startup period was 30 days, the steady state period was 10 days, the chock load

period was 6 days, and return steady state (final stage) was 13 days.

The stability of effluent COD concentration was used as a primary indicator of steady state conditions. The measurement of effluent COD concentrations was made by sampling the effluent treated water daily during the start-up period.



Figure5. Reactor A, reactor B and reactor C systems and laboratory apparatus, general view

- Measurements and analysis methods

Chemical oxygen demand (COD) of the influent and effluent, pH value of the influent and effluent, Temperature are the parameters determined during the experimental work. Mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), suspended solids (SS), and food to microorganism's ratio (F/M) are the parameters carried out on the sludge.

All the parameters were determined in accordance with (Standard Method for the Examination of water and wastewater.1995) [15].

III. Results and Discussion

The values of COD and PH for startup stages for three reactors illustrates in Table and chart as follows: Table 1 and "Fig6" shows the COD and PH for (reactors A, B, and C) .

A. Start-up and Acclimation

a) The first scenario (conventional reactor)

The ABR consists of five compartments with 38 L of aerobic granular biomass. This biomass was divided evenly between each of the five compartments within each reactor (i.e. 7.6 L/compartments). In order to achieve a steady state, the biomass was acclimated into anaerobic condition by feeding a small value of OLR (0.9 kg COD/L) after that, this value was gradually increased to 2.5 kg COD/L. The steady state operation was determined to be a series of HRT or 2days, which is longer, where the effluent COD concentrations remained constant. Liquid samples were tested from the effluent wastewater for the start-up stage. The duration of this stage was 30 days. It could be noted that the removal efficiency from the fifteenth day to the twenty fourth day achieved the steady state due to anaerobic system adaptation.

TABLE1. THE COD REMOVAL DURING START-UP

At Days	Influent		Effluent					
	All scenarios		Ssenario 1		Ssenario 2		Ssenario 3	
	COD	P H	COD	PH	COD	PH	COD	PH
0	1800	8.5	-	-				
2	1800	8.5	1374	7.0	931	7.6	1078	7.5
4	1800	8.5	1187	7.00	978	7.5	1368	7.2
7	1800	8.5	1130	7.0	1059	7.3	1035.3	7.2
9	1800	8.5	1106	7.0	845	7.4	1023	7
13	2000	8.5	950	7.0	530	7.5	810	6.9
15	2250	8.5	500	7.0	450	7.3	550	6.9
17	2500	8.5	532	7.0	353	7.2	518	7
21	3000	8.5	614	7.0	500	7.1	590	6.9
24	4000	8.5	1018	6.9	678	7.0	480	6.8
27	5000	8.5	775.9	7.0	502.4	7.0	252.2	6.9

“Tab1.” shows the relation between COD removal efficiency and time for different influent COD concentration (1800, 2000, 2250, 3000, 4000 and 5000 mg/l), flow relate was 38 l/d and pH values ranged between 8.5 and 8.54.

The observed results show that, the COD removal efficiency ranged from 23.97 % to 77.78 % after 15 working days. After that this efficiency became 74.55 % after 27 days with average value equals of 76.16 %

It can be concluded that the COD removal efficiency increased with the increase of influent COD concentration. Also, the COD removal efficiency increased with time due to system adaptation and biomass generation.

b) The third scenario (Sponge bio-film) (Reactor B)

For the same condition, (table 1) illustrates that, the COD removal efficiency ranged from 48.28 % to 73.50 % after 13 working days. After that this efficiency became 89.95 % after 27 days with average value equals of 82.6 %.

C) The third scenario (Fiber bio-film) (Reactor C)

Like the same conditions, (Tab 1) shows that, the COD removal efficiency ranged from 40.11 % to 75.56 % after 15 working days. After that this efficiency became 94.95 % after 27 days with average value equals of 83.6 %.

From these results in” Fig6” that, the Use of bio-film sponge improves the start-up stage by 6%, while the use of fiber improves the start-up stage with 11% for the conventional reactor. It can be concluded from this figure that, the ABR (B) and ABR (C) gave the highest % COD removal comparing with ABR (A), where reactors B and C were faster to adapt the anaerobic treatment.

As pH is the most important control parameter in the anaerobic process, and each microbial group involved in

anaerobic degradation has a specific pH range for optimal growth. The optimum pH range for specific hydrogen production rate is 5.5 – 5.7. [16], [17]. For methanogenic microbes the pH range is 6.5 – 7.5 [18]. Acidogenic bacteria produce organic acid, which tend to lower the pH of the anaerobic reactor. Under normal conditions, this pH reduction is buffered by the calcium bicarbonate produced by methanogens [19].

Through the comparison between three scenario regarding effluent PH values for influent COD concentration (1800, 2000, 2250, 2500, 3000, 4000, 5000) mg/l, flow rate 38l/h and influent pH equal 8.5. It can be concluded that, the three reactors maintain to alkalinity in this stage.

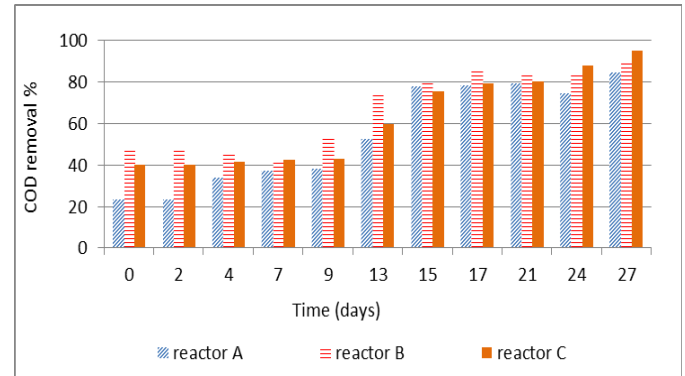


Figure6. Comparison between the reactors in start up

iv. Conclusions

Based on the observations and the results from this study, the following points were concluded:

- 1- The anaerobic baffled reactor with fiber bio-film ABR(C) system gave the highest COD % removal comparing with the other systems (conventional anaerobic baffled reactor and anaerobic baffled reactor with sponge bio-film) due to large void ratio in fiber media, also may be surface type for this media Creates a suitable surface for the breeding of bacteria.
- 2- The use of backing media in the anaerobic baffled reactor improves the removal efficiency according to the type of media in startup phase .The fiber improves the removal efficiency by 11%, while the sponge improves the removal efficiency of the anaerobic reactor by 6%.
- 3- The use of media in the anaerobic baffled reactor gives an acceptable efficiency in all compartments due to the presence of media.
- 4- Increasing the influent COD concentration decreases the effluent pH value. Also, the pH value decreased with time which leads to decreases the COD % removal.
- 5- Must maintain on the temperature and pH during the period of treatment and keep the characteristics of attached media for order to be ABR (c) the highest COD % removal.

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