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Applications of Anaerobic Baffled Reactor in Wastewater Treatment using Agriculture Wastes

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Abstract - *The use of anaerobic baffled reactor for wastewater treatment along with its development, applicability and possible future application is presented in this research. The reactor design has been developed since the early 1980s and has several advantages over well-established systems such as the up flow anaerobic sludge blanket and the anaerobic filter. From these advantages are better resilience to hydraulic and organic shock loadings, longer biomass retention times, lower sludge yields, and the ability to partially separate between the various phases of anaerobic catabolism. The latter causes a shift in bacterial populations allowing increased protection against toxic materials and higher resistance to changes in environmental parameters such as pH and temperature. The physical structure of the anaerobic baffled reactor enables important modifications to be made such as the implementing of an aerobic polishing stage, resulting in a reactor that can treat difficult wastewaters which currently require several units, ultimately significantly reducing capital costs. The main objective of this study is to investigate the behavior of three reactors and verify the use of the bio- film in improving treatability, to reach the mentioned goal two types of bio-films; ficus fiber and palm fiber were used and investigated. However, during the study 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 all the reactor stages (start-up, steady state, shock load and final stage), and effluent COD concentration, pH in all compartment from reactors during shock load stage were measured and recorded. Test results revealed that the ABR (C) scenario gave the highest COD % removal comparing with the other two scenarios*

Key Words: Anaerobic baffled reactor, organic load rate, Biomass, solids retention time, hydraulic retention time

1. INTRODUCTION

One of the major investments of Wastewater Treatment Plants are high capital cost of Operation and Maintenance, in return they represent one of the major investments. However, developing countries suffer from a clear obstacle, which is the lack of funding that results in inappropriate operation condition of wastewater treatment plants. Moreover, increase in population densities found in huge residential complexes can be controlled and served by decentralized systems which have simpler techniques and cost effective [1]. Rapid urbanization and increasing population with minimum availability of land has become an obstacle for installing centralized sewage treatment plant, which became a non-reliable option. The huge capital investment of sewerage systems and pumping costs accompanied with centralized systems can be reduced, resulting in increase of the affordability of wastewater management systems. With the improvement of world economic condition, water resources are becoming increasingly deficient and the quality of environment conditions in the world is constantly becoming worse in most regions. Water protection and waste management are two extremely important global issues to world population. Therefore, it is necessary to reuse wastes and to implement low-cost methods for wastewater treatment. Wastes from agriculture and industry activities are a major problem caused by the increasing of food demand. The potable water shortage is mainly due to the high costs required for water treatment due to different operation parameters such as; area need, operation techniques difficulties and low investments in such field with the absence of calibres and innovation. To overcome these problems, it has been found that it is necessary important to resort to fast processing techniques. Treatment and disposal of wastewater is presently one of the serious environmental problem contributors. Therefore, there is a desire to develop reliable technologies for wastewater treatment.

Wastewater is commonly used to describe liquid wastes that are collected and transported to a treatment facility through a system of sewers. Anaerobic process for wastewater treatment has attracted increasing attention in the recent decades. 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 (Saktaywin et al., 2005[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 techniques. To achieve different levels of contaminant removal, individual waste-water treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary waste-water treatment. More rigorous treatment of waste-water includes the removal of specific contaminants as well as the removal and control of nutrients. Biological unit processes are used to convert the finely divided and dissolved organic matter in waste-water into flocculent settle able organic and inorganic solids. Biological processes are usually used in conjunction with physical and chemical processes, for the main objective of reducing the organic content (measured as BOD, TOC or COD) and nutrient content (notably nitrogen and phosphorus) of wastewater. Anaerobic treatment includes decomposing and dissolving complex organics to forming end-products (e.g., CH_4 and CO_2), anaerobic degradation is a complex process. Anaerobic treatment processes include anaerobic suspended growth, up flow and down flow anaerobic attached growth, fluidized-bed attached growth and up flow anaerobic sludge blanket (UASB).

General design considerations for anaerobic treatment processes. The type of wastewater and its characteristics are important in the evaluation and design of anaerobic processes. The characteristics presented here apply to the suspended growth, sludge blanket, attached growth, and other anaerobic processes.

Important factors and wastewater characteristic that need to be considered in the evaluation of anaerobic processes for wastewater treatment are discussed below. Food processing and distillery wastewaters, for example, can have COD concentrations ranging from 3000 to 30000 mg/L. other considerations that may apply to different wastewater sources are the presence of potential toxic stream, flow variation inorganic concentration, and seasonal load variation. Anaerobic processes can respond quickly to wastewater feed after long periods without substrate addition. In some cases, with warmer climates, anaerobic treatment has also been considered for municipal wastewater treatment

1.1 Anaerobic Baffled Reactor

In the anaerobic baffled reactor (ABR) process, baffles are used to direct the flow of wastewater in an up-flow mode through a series of sludge blanket reactors. The sludge in the reactor rises and falls with gas production and flow. But moves through the reactor at a slow rate. Various modifications have been made to the ABR to improve performance. The modifications include, 1) changes to the baffle design, 2) hybrid reactors where a settler has been used to capture and return solids, or, 3) packing has been used in the upper portion of each chamber to capture solids (Barber and Stuckey, [3]). Though granulated sludge is not considered essential for the operation and performance of the ABR process. Several studies have been done with the ABR process at bench and pilot scale for a wide range of wastewaters and temperatures as low as 13^{o}C.

An excellent summary of these studies including organic loading rates, temperature, and percent COD removal is provided by (Barber and Stuckey, [3]). Typical design loadings for the ABR process are presented in Table-1. Many of these studies were operated at T values in the range of 6 to 24 hrs. The reactor volatile solids concentrations varied from 4 to 20 g/liter.

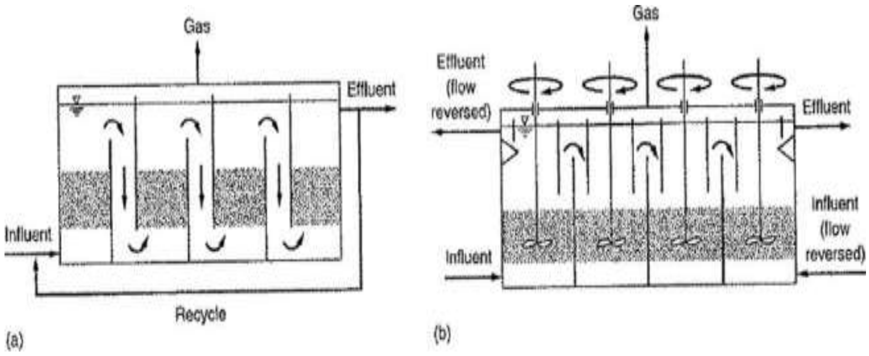

Fig -1: Schematic views of alternative sludge blanket processes: (a) anaerobic baffled reactor (ABR) and (b) anaerobic migrating blanket reactor (AMBR)

The advantages for the ABR process include simplicity; no packing material, no special gas separation method, no moving parts, no mechanical mixing, and little plugging potential, long SRT possible with low hydraulic retention time HRT and no special biomass characteristic required. The ABR can also handle wastewater with a wide variety of constituent characteristics can be treated. It is also known for stable performance to shock loads.

Table -1: Design and performance results from bench and pilot scale studies on anaerobic treatment of various wastewater with the ABR process

Wastewater	Temperature	Number of chambers	Influent COD mg/L	COD loading $Kg/m^3/d$	Percent COD Removal
Carbohydrate/ protein	35	5	7100-7600	2-10	79-82
Distilling	35	5	51,600	2.2-3.5	90
Carbohydrate/ protein	35	5	4000	1-2	94
Molasses	35	3	115,000-900,000	4.3-28	49-88
Swine manure	35	3	58,500	4.0	62-69
Municipal wastewater	18-28	3	264-906	2.2	90
Slaughterhouse	25-30	4	450-550	0.9-4.7	75-90
Pharmaceutical	35	5	20,000	20	36-68
Domestic /industrial	15	8	315	0.9	70
Glucose	35	5	1000-10,000	2-20	72-99

1.2 Anaerobic migrating blanket reactor

The anaerobic migrating blanket reactor (AMBR) process is like ABR with the added features of mechanical mixing in each stage and an operating approach to maintain the sludge in the system without resorting to packing or settlers for additional Solids capture (Figure-1-b). In the AMBR process, the influent feed point is change periodically to the effluent side and in return the effluent withdrawal point is also changed. In this way the sludge blanket remains more uniform in the anaerobic reactor. The flow is reversed when a significant quantity of solids accumulates in the last stage. The AMBR process has been shown to be feasible from bench –scale testing treating non-fat dry milk at 15 and 20^{o}C. The organic loading rate was varied from 1.0 to 3.0 kg $COD/m^3/d$ with hydraulic retention time ranging from 4 to 12 hrs. At the higher COD loading, the COD removal efficiency was 59 % at 15^{o}C. At 20^{o}C, COD removals ranged from 80 to 95 % at COD loading of 1 to 2.0 $kg/m^3/d$, [4]

2. MATERIALS AND METHODS

Pilot plants used in this study were constructed in the Laboratory of Sanitary Engineering, Civil Engineering Department in Faculty of Engineering Alexandria University.

The experimental studies performed were categorized into five main parts; preparation of the samples, design of the reactors, identifying the characteristics of the media used, operation of the reactors and finally analyzing and evaluating.

According to (Battistoni, Gava G. & Ruello M.L.), the activated sludge process utilizing a synthetic wastewater was prepared by diluting tap water (1-100) a concentrated stock solution containing 48 g/l glucose, 11.65 g/l $Na_3PO_4 12H_2O$ and 8.8 g/l $(NH_4)_2SO_4$. The synthetic wastewater was daily prepared fresh. The diluted solution has average COD concentration equals to 500 mg/L. Three bench scale ABRs were carried out in a parallel mode. ABR is constructed from 5mm thick transparent Perspex, with internal dimensions of 80 cm long, 25 cm width and depth of 50 cm with working volume of 76 l cm^3. 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 cm and width of down comer is 4cm, the lower part of the down- comer baffles was angled at 45 to direct the flow evenly the up comer. Each compartment is equipped with sampling ports. As indicated in Boopathy. Anaerobic baffled reactor 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 1000 mg /l, O.L.R equal 2 kg COD/m^3/d, and Q equal 1.58 l/h all these criteria from table (1) (Metcalf & eddy [4]). To determine the total liquid volume below the gas collectors, an effectiveness factor is used, which is the fraction occupied by the sludge blanket. Considering the effectiveness factor, which may vary from 0.8 - 0.9. The experimental work was carried out by operating the activated sludge (AS) pilot plant to anaerobic sludge by providing anaerobic conditions in the reactor. Samples were withdrawer from the collection tank after the settling tank for AS. The 38 L of biomass was divided evenly between each of the five compartments within each reactor (i.e. 7.2 liter /compartment). The sludge contains MLSS = 25000 mg/l, and MLVSS = 19875 mg/l. First the wastewater flowed from the top to the down flow section in the first compartment, clown through the first biomass bed and then up through the biomass bed in the up-flow section of the compartment. The wastewater then spilled over the upcoming baffle into the following compartment and repeated the process, eventually exiting from the exit port at the top of the up-flow section of the five compartments. The recycle fraction was drawn from the top sample port in the final up-flow section. The reactor effluent exited through the outlet port and flowed collection tank. The reactor was operated under mesophilic condition maintained constant at 35 ^oC (Metcalf & eddy [4], and N don, et al [5]). Keep the temperature by a temperature regulator (Heater) placed in each chambers reactor. Synthetic wastewater was prepared daily on fresh basis. The feeding takes place through a 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 the inflow discharge. Use the constant head tanks with system instead of peristaltic pump to avoid power outage.

3. RESULTS

A simple experimental set-up was used to study the treatability aspect of wastewater. Three types of scenario, i) convention anaerobic baffled reactor {ABR (A)}, ii) anaerobic baffled reactor with ficus fiber used {ABR(B)}, iii) anaerobic baffled reactor with palm fiber used {ABR(C)}, where experimental under different organic load rate (1.0, 1.1, 1.2, 1.4, 1.6, 1.8, 2.0 and 4.0 kg COD /m^3/d), constant flow rate 38 l/d with initial COD concentration 500 mg/l. pH value effect on treatability was also investigated. The ABR (C) system gave the highest COD % removal comparing with the other two systems. Result showed that decreased effluent of pH value had an adverse effect on treatment efficiency for all cases.

3.1 Convention anaerobic baffled reactor

The COD removal efficiency ranged between 23.97 to 79.53% with average value 55.1 % after 27 working days in start-up stage, for influent COD concentration ranged between 500 to 1000 mg/l and flow rate 38 l/d. The COD removal efficiency ranged between 73 to 84.48 % with average value 73.48% after 13 working days in steady state stage for influent COD concentration 1000 mg/l and flow rate 38 l/d, ranged between 17.66 to 59.57% with average value 30% after 6 working days in shock load stage for influent COD concentration 2000 mg/l and flow rate 38l/d. The COD removal efficiency ranged between 18 to 38.42% after 13 working days in final stage for COD concentration 1000 mg/l and flow rate 38 l/d.

The effluent pH value ranged between 6.91 to 7.05 in start- up stage for influent COD concentration ranged between 500 to 1000 mg/l, ranged between 6.3 to 7.02 in steady state stage for influent COD concentration 1000 mg/l, ranged between 5.45 to 6.4 in shock load stage for influent COD concentration 2000 mg/l and ranged between 5.5 to 5.8 in final stage for influent COD concentration 1000 mg/l.

3.2 For Anaerobic baffled reactor with ficus fiber bio-film

The COD removal efficiency ranged between 48.28 to 83.05% with average value 64.22 % after 27 working days in start-up stage, for influent COD concentration between 500 to 1000 mg/l and flow rate 38 l/d. The COD removal efficiency ranged between 83.1 to 89.9% with average value 88.37% after 13 working days in steady state stage for influent COD concentration 1000 mg/l and flow rate 38 l/d, ranged between 13.3 to 33.41% with average value 22.6% after 6 working days in shock load stage for influent COD concentration 2000 mg/l and flow rate 38l/d. The COD removal efficiency ranged between 15.7 to 35.98% after 13 working days in final stage for COD concentration 1000 mg/l and flow rate 38 l/d.

The effluent pH value ranged between 7.05 to 7.6 in start-up stage for influent COD concentration ranged between 500 to 1000 mg/l, ranged between 6.9 to 7.12 in steady state stage for influent COD concentration 1000 mg/l, ranged between 4.97 to 5.56 in shock load stage for influent COD concentration 2000 mg/l and ranged between 5.5 to 5.9 in final stage for influent COD concentration 1000 mg/l.

3.3 Anaerobic baffled reactor with palm fiber bio-film

The COD removal efficiency ranged between 40.11 to 88.00% with average value 61.18 % after 27 working days in start-up stage, for influent COD concentration between 500 to 1000 mg/l and flow rate 38 l/d. The COD removal efficiency ranged between 90.88 to 94.95 % with average value 93.07% after 13 working days in steady state stage for influent COD concentration

1000 mg/l and flow rate 38 l/d, ranged between 19.25 to 81.11% with average value 40.9% after 6 working days in shock load stage for influent COD concentration 2000 mg/l and flow rate 38l/d. The COD removal efficiency ranged between 20.36 to 39.94% after 13 working days in final stage for COD concentration 1000 mg/l and flow rate 38 l/d.

The effluent pH value ranged between 6.97 to 7.5 in start-up stage for influent COD concentration ranged between 500 to 1000 mg/l, ranged between 6.99 to 7.12 in steady state stage for influent COD concentration 1000 mg/l, ranged between 5.52 to 6.97 in shock load stage for influent COD concentration 2000 mg/l and ranged between 5.42 to 5.88 in final stage for influent COD concentration 1000 mg/l.

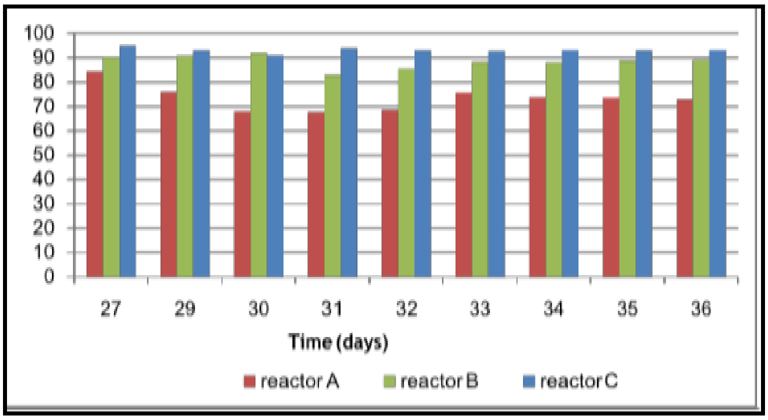

Chart -1: Removal Efficiency of COD for the three reactors (A, B, and C) in Steady State Stage

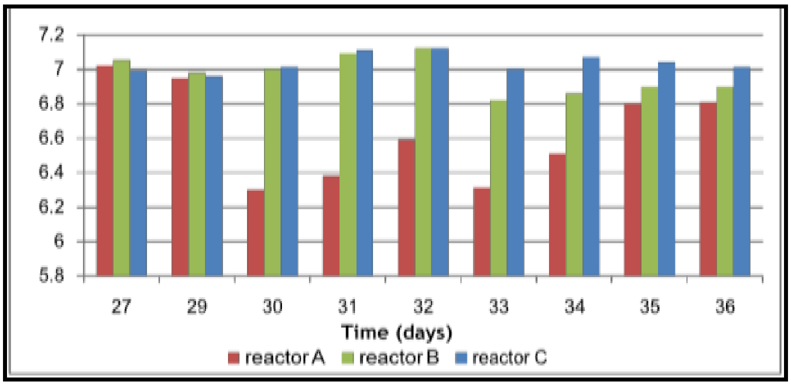

Chart -2: Effluent pH for the three reactors (A, B, and C) in Steady State Stage

4. CONCLUSIONS

In this paper we have reviewed different techniques for the anaerobic wastewater treatment using agriculture wastes. The anaerobic baffled reactor with palm 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 ficus fiber bio-film) due to large void ratio in palm fiber media, also may be surface type for this media Creates a suitable surface for the breeding of bacteria. The sudden increase in the influent COD concentration (shock load) decreased the COD removal efficiency in all scenarios. Also, the COD removal efficiency decreased with time.

The use of backing media in the anaerobic baffled reactor improves the removal efficiency according to the type of media. Palm fiber improves the removal efficiency by 27 %, while the ficus fiber improves the removal efficiency of the anaerobic reactor by 20 %. The use of media in the anaerobic baffled reactor gives an acceptable efficiency in all compartments due to the presence of media. Increasing the influent COD concentration decreases the effluent pH value. Also, the pH value decreased with time which leads to decrees the COD % removal. It 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. Results showed that decreasing pH value had an adverse effect on treatment efficiency for all cases.

REFERENCES

[1] Allawi, R., Ahmad, A., Ismail, N., and Kadir, M., —Anaerobic co-digestion of palm oil mill effluent with rumen fluid as a co-substrate|| Desalination, V. 269, November.2011, pp. 50-57.

[2] Saktaywin, W., Tsung, H., Nagore, H., Soyama, T., and Weerapakkaroon J. —Advanced sewage treatment process with excess sludge reduction and phosphorus recovery||. Water Recourse, V. 39, (2005), pp 902-910.

[3] Barber, W., and Stuckey, D., —The Use of the Anaerobic Baffled Reactor (ABR) for wastewater Treatment: A Review, || Water Research, V. 33, (1999), pp. 1559-1578.

[4] Metcalf & eddy, —Wastewater Engineering Treatment and Reuse, || Mc Graw Hill Book CO., New York, International Edition, 2003.

[5] Ndon, U., and Daegu, R., —Effects of Temperature and Hydraulic Retention Time on Anaerobic Sequencing Batch Reactor Treatment of Low-Strength Wastewater‖ Water Research, V. 10, (1997), pp. 2455-2466