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IMPACTS ON THE pH LEVELS FOR THE CONVERSION OF VOLATILE FATTY ACIDS IN AN INTEGRATED ANAEROBIC BAFFLED REACTOR

ASHA B.*, N. SIVARAMAN AND S. RAJKAMAL****

Department of Civil Engineering, Annamalai University, Chidambaram, T.N., India

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Key words : *Acidogenesis, Anaerobic Migrating Blanket Reactor, Chemical Oxidation Demand, Hydraulic Retention Time, Methanogenesis, pH, Volatile Fatty Acids.*

Abstract – The real time institutional wastewater was used during the experimental study period. Institutional wastewater contains high levels of organics as evidenced by Chemical Oxygen Demand (COD), Volatile Suspended Solids (VSS), Volatile Fatty Acid (VFA), Nitrogen, Potassium and Phosphorus and large amount of suspended solids. A laboratory scale Anaerobic Migrating Blanket Reactor was designed and fabricated. AMBR was accomplished with both suspended and attached growth process. The reactor has been continuously operated at mesophilic range. A low initial organic loading rate was beneficial for the growth of anaerobic active sludge and the low COD organic loading resulted in low production of gas rate and low wastewater up-flow velocity. The reactor has five compartments and accomplished with both suspended and attached growth processes. Temperature of the reactor was maintained under mesophilic range. The influence of VFA for the growth of acidogenic and methanogenic organisms with respect to the reduction of organic substance was analysed. The entire experimental work was carried out with the Hydraulic Retention Times of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 5.0 and 6.0 days with six average influent Chemical Oxidation Demand of 888, 768 and 656, 1064, 1168 and 1304 mg/L. Increased level of VFA in the second compartment was due to the production of acetic acids and acetate during the digestion process. The anaerobic path way from the first to fifth compartment in terms of COD reduction was estimated due to the influence of pH.The influent in the compartment 1 had hydrolysed to simple organics. This results demonstrated that the VFA had been converted to acetate and hydrogen gas by acetogens in the compartment (1 and 2), and these intermediates were then further converted to methane by methanogens in the subsequent compartments (3, 4 and 5). The behaviour of the VFA concentration in the 5th compartment demonstrated that hydrolysis and acidogenesis were the important biochemical activities occurring in the first 2 compartments, whereas methanogenesis dominated in the last 2 compartments. The maximum and minimum VFA concentration is 336 to 45 mg/L respectively. It may be the result of acclimatization of methanogenic bacteria which partly began to degrade organic acid.

INTRODUCTION

Water pollution becomes one of the chief concerns of civilized society; the more a society moves towards advancement the more it prone to pollution of water. Number of factors are responsible for water pollution: rapid growth of cities, establishment of large number of institutions, the inevitable use of chemical manure and the various types of chemicals for the control of pests and insects in the field of agriculture, discharge of sewage into the rivers and dumping of waste material both organic and inorganic on water bodies like lakes, rivers, ponds and wells.

The Institutional wastewater, which is biodegradable, can be biochemically treated under the purview of the present study. Many treatment methods are available for removing the chemicals and biodegradable organics. Treatment methods like physico-chemical and Biochemical methods are the widely applied methods in the treatment process of the institutional wastewater. Moreover Biological methods are preferred for their cost effectiveness and environment friendly nature. Biological methods are the well-liked and smart technology that utilizes the metabolic potential of microorganisms to clean up the environment. The ABR was first built up by Batchmann *et al.*, 1983 and explained as a series of up-flow anaerobic sludge bed blankets (UASBs). This design consisted of a series of vertical baffles to force wastewater to flow up and down through a series of compartments containing the mixed anaerobes as they passed from the inlet to the outlet (Wanasen, 2003). Langenhoff *et al.* (2000) claimed that the ABR's most significant advantage is its ability to isolate acidogenesis and methanogenesis longitudinally down the reactor. This technology supports the diverse microbial culture to build up under most productive conditions, and the reactor performs as a di-phasic system without the association of high cost-control problems. This system of operation can increase acidogenic and methanogenic activities independently. Based on the study of Boopathy, 1998, as compared to two to three chambers, the four- and five-chambered ABRs appear to be slightly more efficient in converting solids and biogas. According to Sasse, 1998, the anaerobic baffled reactor is easy to build and simple to function with modest effect of Hydraulic and organic shock loads.

The sludge is made up of microbial granules that resist being washed out with the flowing water because of their weight. The baffles also prevent the washing out of the sludge. These microbes in the sludge degrade the organics present in the wastewater flowing through. As a result of this anaerobic degradation, gases like methane and carbon dioxide are produced. The anaerobic digestion in the ABR is accomplished by three groups of micro organisms. The first one is the acidogenic, which convert complex polymer substrates into the simpler sugars, alcohols, organic acids, hydrogen and CO_2. The second being the acetogenic and hydrogen producing micro organisms that convert the previous stage products into acetate and CO_2. The third group is the methanogens that convert simple compounds formed in the previous step into methane (Batchmann *et al.*, 1983: Foxon *et al.*, 2007). The anaerobic baffled reactor (ABR) eliminates the danger such as clogging and sludge bed expansion of the other systems, such as the anaerobic filter and UASB (Manariotis and Grigoropoulos, 2002). A five-chambered anaerobic migrating blanket reactor MABR) was developed to evaluate its suitability for the treatment of Institutional wastewater. In our earlier recent work, the application of AMBR has been studied about the Effect on bifurcation of Acidogenic and Methanogenic Microorganism in a Compartmentalized Anaerobic Migrating Blanket Reactor (Aruna and Asha, 2019). However, sudden transforms in temperature, hydraulic or organic overloading, and the occurrence of inhibitory substances may change the digester stability (Chen *et al.*, 2007). Zickefoose and Hayes (1976) for instance suggested that the ratio VFA's/TA should be maintained in the range of 0.1-0.35mmol per l/ mmol per l in order to improve the digester stability. Recently, Bernard *et al.* (2001b) found that the ratio IA/TA must be less or equal to 0.3mmol per l/ mmol per l in order to avoid the digester instability. Bhuvaneswari and Asha (2007) observed the effect of HRT on the biodegradability of textile wastewater bin an ABR and attained a maximum COD removal efficiency of 91.67% with a HRT of 1.75 days. This research article explains about the configuration, start-up and effect of Hydraulic Retention Time on treatment efficiency for treating Institutional wastewater using anaerobic Migrating Blanket Reactor. Rongrong Liu *et al.*, (2010) and Hexi Zhoua *et al.*, (2018) reviewed about the strategies for enhanced treatmentof municipal/domestic wastewater at low temperature. Wanli Zhang *et al.*, (2019) estimated that the initial pH significantly affected batch anaerobic process and attained the highest organics removal efficiency (94.1%). Pitchaya Suaisoma *et al.*, 2019 found a suitable condition for ABR at the OLR of 4.0 kg COD/m^3.d under the semi-continuous feeding scheme with trace element additions at the effluent recirculation rate of 0.5 (QR/Q). At this condition, high methane yield (0.49 ± 0.05 Nm^3/kg VS added) could be achieved using the economical ABR at relatively high OLR of 4.0 kg COD/m^3.d

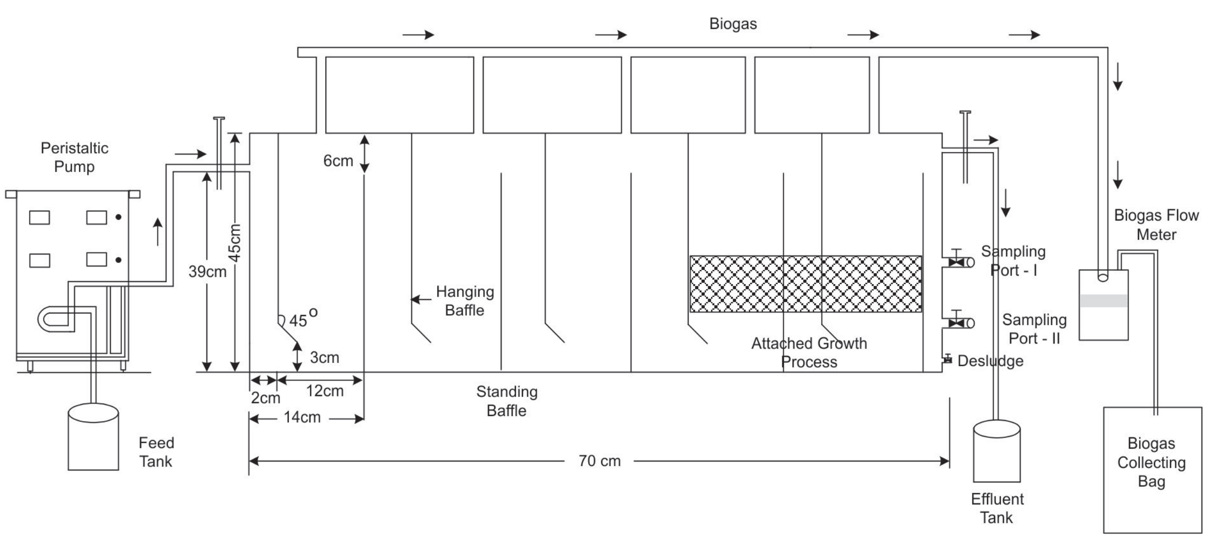
Pak Chuen Chan *et al*. (2017) investigated that the anaerobic co-digestion of a mixture of food waste and domestic wastewater (0.09, v/v) using an upow anaerobic sludge blanket (UASB) reactor to generate renewable energy in form of biogas. Pak Chuen Chan *et al.*, 2018 utilized the supplementation of Micronutrient to enhance the digestion efficiency applied during the anaerobic (co-) digestion process. Ewa Dacewicz 2019 discussed about the assessment of domestic sewage filtration effectiveness with four types of waste serving as filling materials in vertical flow filters. Xiao Zhaa *et al.*, 2019 utilized the modified ABR and achieved average removal efficiencies of 94.05% of chemical oxygen demand (COD), 28.78% of total nitrogen (TN), 14.21% of ammonium nitrogen (NH +-), and 32.54% of total phosphorus (TP) during 112 days of continuous operation.

Gaetan Blandina *et al.,* (2019) observed that VFA rejection by FO membrane is highly connected to pH and the concentration of VFA present in pre-treated real domestic wastewater proved to be more challenging with regards to fouling /biolm formation which favours the biodegradation of VFA. Takuya *et al.,* (2018) investigated the treatment of solid/lipid-rich wastewater with an anaerobic baffled reactor and a down-ow hanging sponge reactor.

Xiaoding Huanga *et al*., (2019) investigated the effect of Clarithromycin (CLA) on volatile fatty acids (VFAs) production during waste activated sludge (WAS) anaerobic fermentation. Experimental results showed that the inhibition to acetogenesis and methanogenesis was severer than that to hydrolysis and acidogenesis, resulting in the decrease in VFAs consumption. Yong Jina *et al.,* (2019) studied the effects of different pH (5.5, 6.5, and uncontrolled) on the VFAs concentration, composition, acidogenic efficiency and microbial community. Zhipeng Li *et al*., (2018) studied the anaerobic co-digestion of food waste and sewage sludge was investigated for the production of hydrogen and volatile fatty acids.

Experimental Methodology

The present research work was carried out to evaluate the performance of Integrated Anaerobic Baffled reactor for treating Institutional wastewater. A laboratory scale Integrated Anaerobic Baffled Reactor was fabricated by white Plexiglass sheets with a total volume of 78.75 litres and installed in the Advanced Environmental Laboratory, Department of Civil Engineering, Annamalai University, Tamil Nadu. The total length of the Integrated Anaerobic Baffled Reactor was 70.00cm; width 25.00 cm and depth 45.00cm having a working volume of 68.25 liters consist of equally five compartments. A proper series-arranged construction of the baffles allows wastewater to flow from up and down inlet to outlet through the sludge bed. The distance from the bottom of the reactor to the hanging baffles in each compartment was about 3cm. The first three compartments contain the cycle of suspended growth and the remainder of the two are with the process of attached growth. In the fourth and fifth compartments, the Bio carriers were filled at random. The microorganisms within the Integrated Anaerobic Baffled Reactor gently rise and settle due to the flow characteristics**.** The reactor's top was sealed, and a valve was mounted for biogas venting. The biogas was calibrated through a biogas flow meter and collected to a bio gas collection bag. The reactor was equipped with one inlet and five outlet ports. Peristaltic pump PP 30 EX was used to pump the influent wastewater to the reactor. Figure 1 shows the schematics for the experimental setup. Figure 2 shows the optical view of bio carriers. Table 1 described the physical characteristics and process parameters of experimental model.



Units: All dimensions are in cm.

Fig. 1. The schematic diagram of an Experimental setup

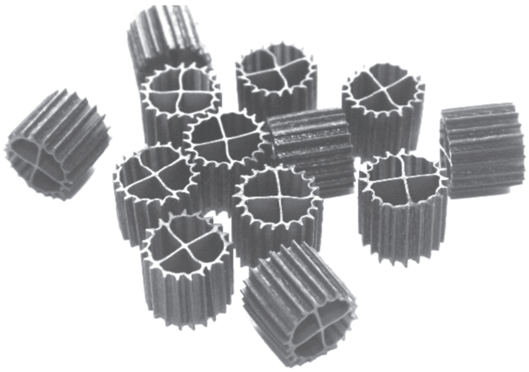


Fig. 2. The Photographic view of bio carriers

Table 1. Physical features and process parameters of Experimental model

Reactor	Dimensions
Length of the reactor	70cm
Depth of the reactor	45cm
Width of the reactor	25cm
Compartment free board	6cm top
Total volume of the reactor	78.75 litres
Working Volume	68.25 litres
Number of compartment	5
Each compartment length	14cm
Peristaltic pump	PP-30

Characterization of Institutional Wastewater

The Institutional wastewater was collected from the Treatment Unit of Annamalai University, Chidambaram, Tamil Nadu. The samples were analyzed and characterized as per the Standard procedure (APHA 2017) which is presented in Table 2.

Start-up of the Reactor

Initially the Institutional wastewater was collected from the wastewater Collection Unit of Annamalai University, Chidambaram, Tamil Naduand characterized the parameters such as Temperature, pH, Total Solids, Total Dissolved Solids, Total Volatile Solids, Chemical Oxidation Demand, Bio Chemical Oxidation Demand, Total Nitrogen, Phosphorous. The above listed evaluates were conducted in accordance with the Normal Water and Wastewater Analysis Methods (APHA, 2017). COD multi photometer was used for analysing COD of the samples; pH of the wastewater was analysed by the digital pH meter. Three sets of samples were collected randomly and analysed. According to the results arrived the levels of Total Solids, Chemically Oxidation Demand, BOD_5 are elevated as compared to the Standard IS10500. The range of Chemically Oxidation Demand in the institutional wastewater was varied from 600 to 900 mg/L, BOD5 was from 300 to 500 mg/L, and Total solids were from 2300 to 5200 mg/Ll.

The samples collected from one inlet and five outlets(Chambers) of the reactor were analyzed for pH, Chemically Oxidation Demand, Volatile Fatty Acids, Volatile Suspended Solids, Biogas collection according to Standard Methods with respect to eight Hydraulic Retention Times of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 5.0 and 6.0 days. The effluents were collected separately from the individual chambers for analysis at each HRT.

The inoculums source granular sludge was collected from the municipal wastewater treatment plant in Chidambaram Municipality, Tamil Nadu, and from the active biomass plant in the Faculty of

Table 2. Characteristics of Realtime Institutional Wastewater

Sl. No.	Parameters	Concentration			Desirable limit as per IS10500
		Trial 1	Trail 2	Trail 3	
1	pH	6.49	6.31	6.73	6.5 to 8.5
2	Turbidity, NTU	9.1	10.2	9.8	5
3	Total Solids, mg/L	1800	2400	2600	500
4	Total Suspended Solids, mg/L	800	1000	1100	100
5	Total Dissolved Solids, mg/L	1000	1400	1500	500
6	BOD_5 @ 20^0C, mg/L	430	430	420	30
7	Chemical Oxygen Demand, mg/L	784	864	920	250
8	Chlorides, mg/L	349	450	548	250
9	Nitrates, mg/L	56	47	68	45
10	Phosphates, mg/L	24	18	28	NA
11	Potassium, mg/L	13	14	13	NA
12	Oil and Grease, mg/L	0.0403	0.0401	0.0483	10
13	Calcium, mg/L	105	95	125	75
14	Magnesium, mg/L	48	39	59	30

Agriculture, Annamalai University, Annamalai Nagar, during the start-up process of Integrated Anaerobic Scrambled Reactor. To remove debris the granules were passed through a screening process. Establishing the most effective microbial population is the overall goal of IABR (Integrated Anaerobic Baffled Reactor) start-up. The Municipal wastewater of approximately 0.123 kg COD/m^3/day was pumped into the reactor by a Peristaltic Pump PP EX 30 with a HRT of 24 h. The feeding of the wastewater was in continuous mode for the biomass acclimatisation. The temperature, pH, Chemically Oxidation Demand and biogas production were monitored with a HRT of 24h in the start up phase. Just frothing was observed on the surface of the wastewater body during the first five days of the reactor start-up. This may suggest some respiratory activity within the reactor but has not resulted in significant output of biogas. The levels of influent and effluent COD was presented in Figure 3. The Chemically Oxidation Demand removal rates, during first five days were very low in the range of 10-20%. The low efficiency for organic pollutant removal was due to the slow growth rate of microbial populations at the commencing of the process. During the period of 6 to 10^{th} days, moderate removal of COD was reached. Up to 12^{th} day, the performance with respect to COD removal efficiency was incremental and from 12^{th} to 15^{th} day, the removal efficiency was in the decremented range which may be due to the accumulation of Volatile Fatty Acid production in the reactor. From 15^{th} day onwards the removal efficiency was increased and become steady state from 18^{th} to 21^{st} day (Figure 4). The incorporation of attached as well as suspended growth system in a single Integrated anaerobic baffled reactor as a novel technology supports the reduction of start up period.

The pH in influent and effluent of the reactor has

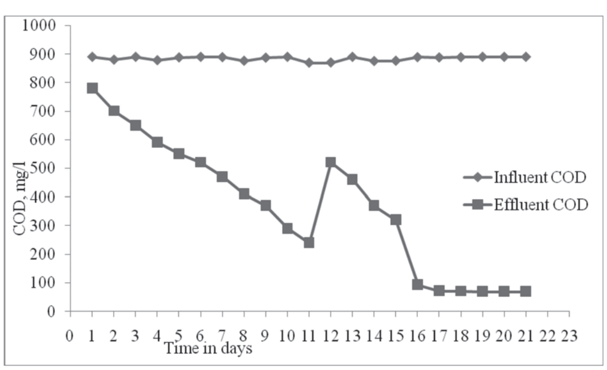


Fig. 3. Time in days Vs Influent COD and Effluent COD during start up process

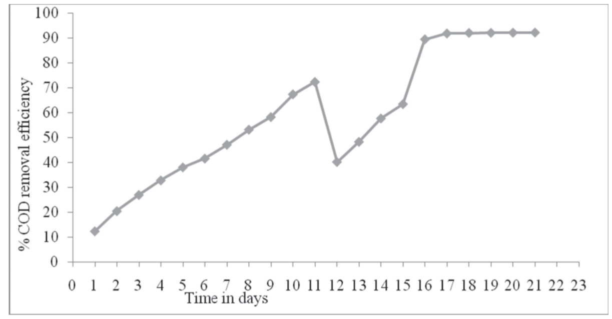


Fig. 4. Time in days Vs % COD removal efficiency during start up process

been analysed regularly. The peak pH reported in most sources is higher than the ideal pH for anaerobic digestion, i.e. 6.5 – 8.7. Influent pH measured from 6.2 to 7.4 though the pH was close to 7.0 before feeding to the influential tank (Figure 5). All influential and effluent temperatures within the 20 to 400C range were well within the mesophilic limit. Biogas production was not constant and stable due to the loss of gas through dissolution in the effluent and desorption of methane at the water surface. The biogas produced in the reactor was very minimum which may be due to the low strength of the wastewater is 0.001 to 0.0014 m^3 of biogas per kg COD removed (Figure 6). After attained a steady state, the influent concentration was gradually increased from 20%, 40%, 60%, 80% and 100% of Institutional wastewater. The COD removal efficiency was controlled after enabling 100 percent concentration of institutional wastewater to achieve a stable removal of Chemical Oxidation Demand.

RESULTS AND DISCUSSION

The Integrated Anaerobic Baffled Reactor output was performed with six operating stages until stable and full removal efficiency of the Chemically

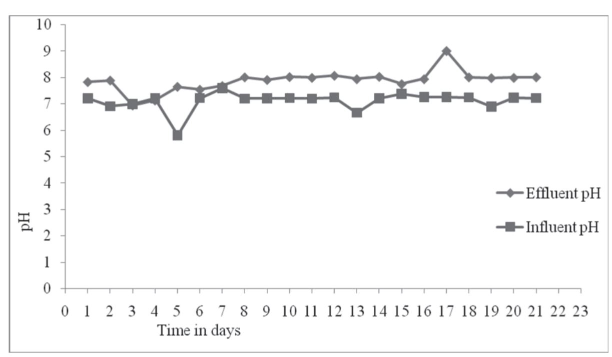


Fig. 5. Time in days with respect to effluent and influent pH during start-up process

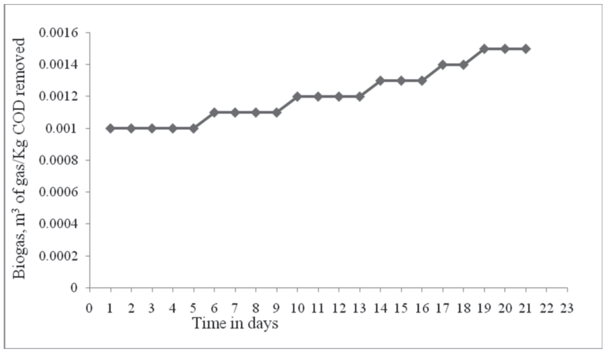


Fig. 6. Time in days with respect to Biogas, m^3 of gas/Kg COD removed during start process

Oxidation Demand was achieved. In stage one, two and three, the raw institutional wastewater without addition of any substrate was allowed with an average influent COD of 888, 768, and 656 mg/L into the Integrated anaerobic baffled reactor(IABR). pH of each compartments in the reactor plays an important role for the digestion of organic substances in the Institutional wastewater. The most significant advantage we found in this Integrated Anaerobic Baffled Reactor was its capacity under favourable conditions to distinguish acetogenic and methanogenic populations within the reactor. Hydrolysis stage was completed in the first compartment by converting complex organic compounds into simpler one. Those simpler compounds are converted into fatty acids and acetate in the second and third compartments by acetogens. In the fourth and fifth compartments the contaminants are further converted by methanogens into methane and carbon-di-oxide. The bio carriers attached in the fourth and fifth compartments stimulates the digestion process effectively. The acetogenic species prevail in the fourth and fifth compartments in the second and third compartments, and the law of methanogens. The pH in the compartment one was from 6.83 to 7.02 in an average influent COD of 888 mg/L. The pH was declined from 6.51 to 6.04 due to the growth of acetogenic population in the second compartment. The pH level was from 6.41 to 5.91 in the third compartment, which showed that the acetogens are still dominated in the third compartment. The value of pH was slightly fluctuated in the fourth compartment from 6.84 to 7.25, which indicated that the prevalence of acid fermentation over methanogens in the fourth compartment (Figure 7). The Volatile Fatty Acids production in this stage was from 52 to 136 mg/L (Figure 13). In the fourth compartment, more incremental pH range defined the stable anaerobic condition for methanogens 'favourable survival. The same scenario was taken place in the second, third, fourth, fifth and also sixth stages. The pH ranges in the first, second, third, fourth and fifth compartments for an average influent COD of 768 mg/L was from 6.66 to 7.26, 5.77 to 6.03, 5.86 to 6.24, 6.84 to 7.30 and 7.31 to 8.12 (Figure 8). The Volatile Fatty Acids production in this stage was from 32 to 103 mg/L (Figure 14). The observed pH in the first to fifth compartments of an average influent COD of 656 mg/L was 6.84 to 7.10, 5.41 to 5.90, 5.86 to 6.23, 6.83 to 7.42 and 7.49 to 8.14 (Figure 9). The VFA level estimated in this stage for all the five compartments are well represented in Figure 15. In stage four with the addition 1 g/L of co substrate the average influent COD was 1064 mg/L, the pH of all compartments are ranged from 5.42 to 8.23. In the fourth stage after addition of 1 g/L of Glucose in the Institutional wastewater, the pH levels in The compartments first, second, third, fourth and fifth were from 7.41 to 7.94, 5.39 to 6.04, 5.81 to 6.65, 7.68 to 7.94 and 7.81 to 8.23 (Figure 10) and Volatile Fatty Acid was from 282 to 311, 403 to 438, 382 to 422, 302 to 328 and 252 to 278 mg/L (Figure 14). The VFA for first to fifth compartments

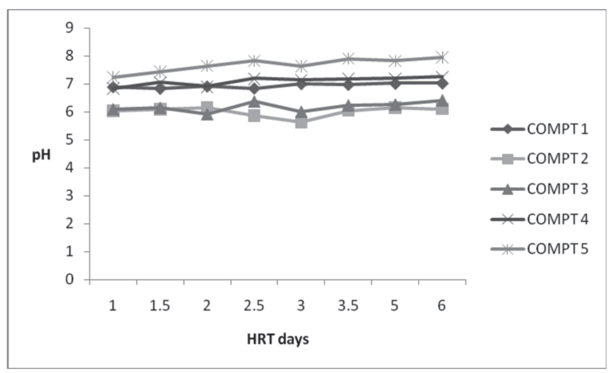


Fig. 7. HRT in days with respect to pH with an average influent COD of 888 mg/L

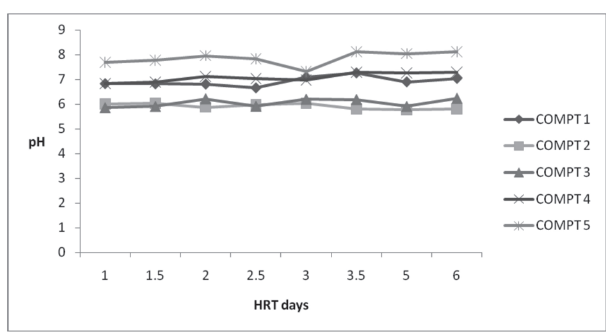


Fig. 8. HRT in days with respect to pH with an average influent COD of 768 mg/L

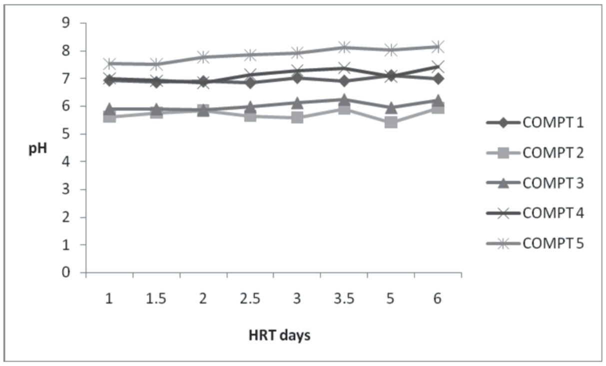


Fig. 9. HRT in days with respect to pH with an average influent COD of 656 mg/L

in stage five with an average influent COD of 1168 mg/L (Addition of 2 g/L of Glucose) was from 307 to 342, 441 to 489, 419 to 465, 331 to 367 and 276 to 306 mg/L (Figure.17). The pH level in this stage was briefly represented in Figure 11. For the final stage with an influent COD of 1304 mg/L (3g/L of Glucose) the Volatile Fatty Acid levels in the effluents of first to fifth compartments were 337 to 378, 480 to 540, 457 to 513, 360 to 405 and 300 to 338 mg/L (Figure 18). All the six stages the pH level was dropped in the second compartment with the range from 5.33 to 6.16 (Figure 12) during the digestion period, which indicated that the organic pollutants hydrolyzed from the compartment one, were fermented to Volatile Fatty Acids by acetogens. Further the ranges of pH in compartments fourth and fifth were incremental Because of the Volatile fatty acids are efficient intake. The lowest range of pH was 5.33 and highest 8.23 for all six stages. The low pH level was identified in the second compartment as compared to the other

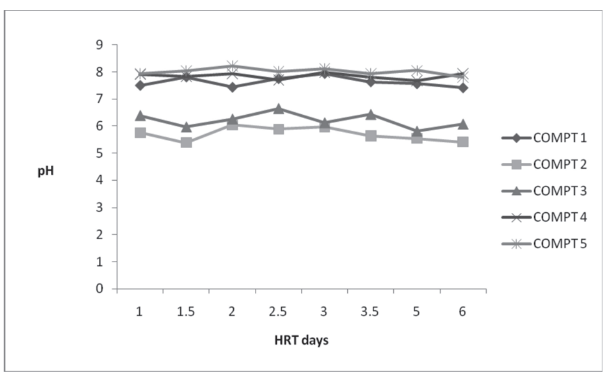


Fig. 10. HRT in days with respect to pH with an average influent COD of 1064 mg/L

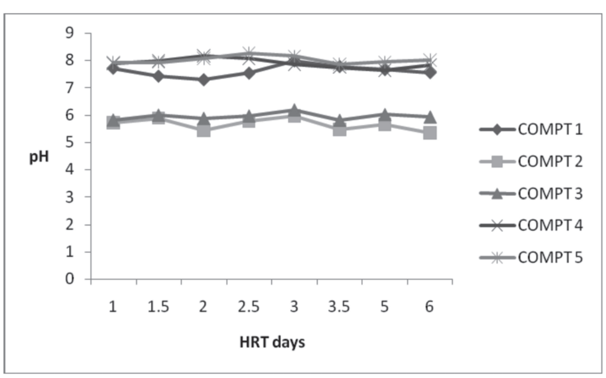


Fig. 11. HRT in days with respect to pH with an average influent COD of 1168 mg/L

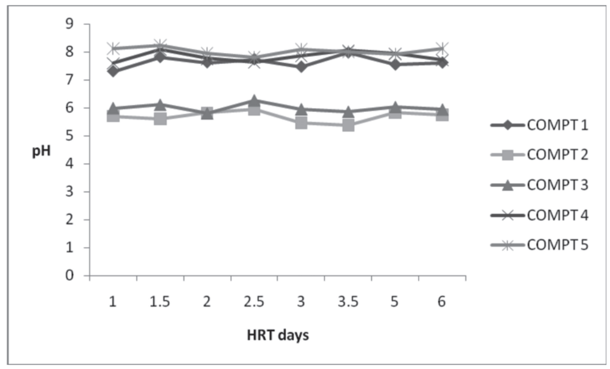


Fig. 12. HRT in days with respect to pH with an average influent COD of 1304 mg/L

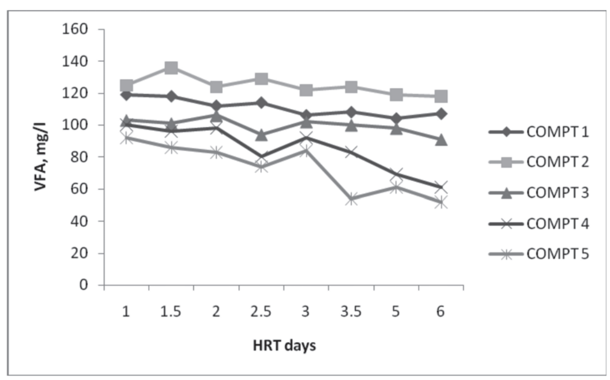


Fig. 13. HRT in days with respect to VFA in mg/L with an average influent COD of 888 mg/L

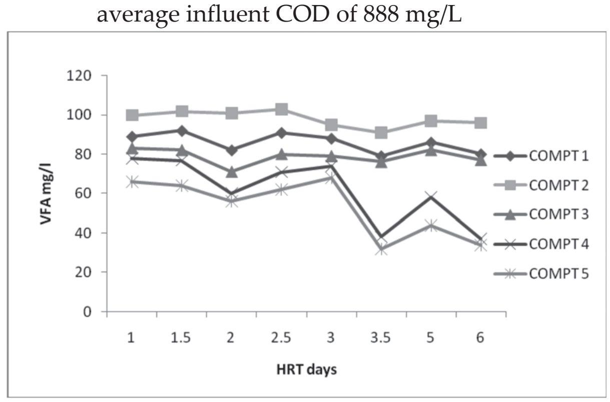


Fig. 14. HRT in days with respect to VFA in mg/L with an average influent COD of 768 mg/L

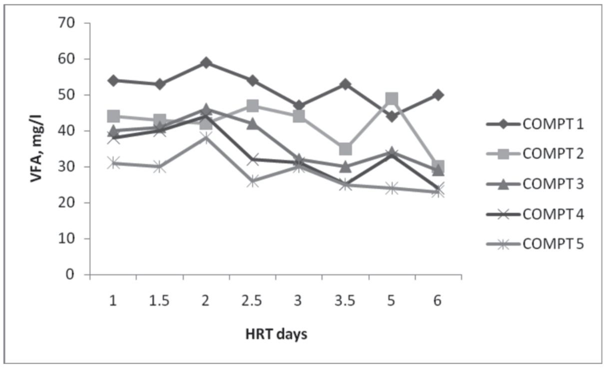


Fig. 15. HRT in days with respect to VFA in mg/L with an average influent COD of 656 mg/L

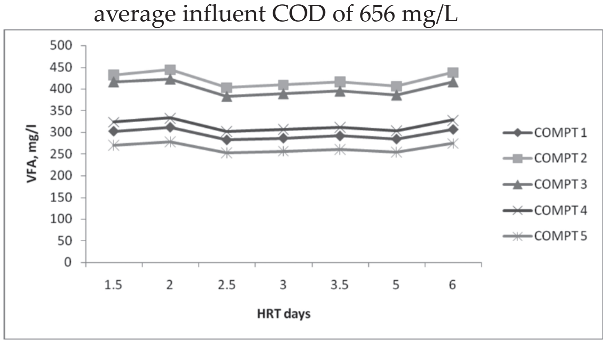


Fig. 16. HRT in days with respect to VFA with an average influent COD of 1064 mg/L

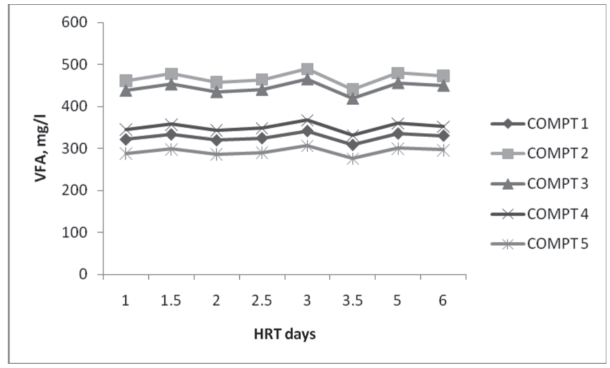


Fig. 17. HRT in days with respect to VFA with an average influent COD of 1168 mg/L

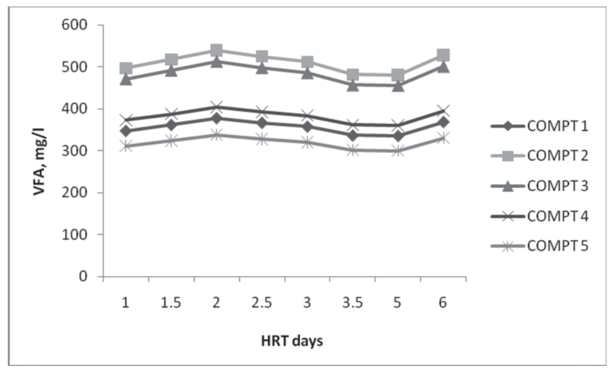


Fig. 18. HRT in days with respect to VFA with an average influent COD of 1304 mg/L

compartments, which showed that the acetogens are more dominated in the second compartment of Integrated Anaerobic Baffled Reactor.

CONCLUSION

The characteristics of Institutional wastewater was investigated and categorized as medium strength of wastewater. Due to the influence of pH and VFA, the anaerobic route from the first to fifth compartment in terms of COD reduction was calculated. Due to the lower pH level in the first two compartments viz 6.7 and 5.9 the methanogenic metabolism population was hindered. The gradual pH range in the fourth and fifth compartments showed that the cycle of metabolism was in methanogenic. The effect of pH with respect to the reduction of organic material has been studied for the growth of acidgenic and methanogenic species. Due to the acid accumulation in the reactor, the VFA concentrations were high and dampen the pH rate which inhibits hydrolysis and acid phase. The decreased pH level in the second compartment was due to acetic acid and acetate generation after the digestive process. The maximum VFA was identified in all sets of the second compartment ranging from 136 to 540 mg/L, which showed that all the stages the second compartment were dominated with the acetogenic populations. The minimum limits of VFA were ranged from 52 mg/L in the fifth compartment. From this study hydraulic shock loads due to the accumulation of VFA was not identified due to the bifurgation of acetogens and methanogens. The Hydraulic retention time influences the performance of the reactor during treatment process.

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