International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-8, Issue-3S, February 2019

The Effect on Bifurcation of Acidogenic and Methanogenic Microorganism in a Compartmentalized Anaerobic Migrating Blanket Reactor

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ABSTRACT--- A laboratory scale experimental setup was performed to develop a compartmentalized Anaerobic Migrating Blanket Reactor (AMBR) for treating an institutional wastewater. Each compartment has a volume of 14.55 litres. Temperature of the reactor was maintained under mesophilic range. The reactor was accomplished with both suspended and attached growth processes. The high concentration of VFA during anaerobic process can inhibit the methanogenic activity. The pH level of each compartment was analysed. The influence of pH 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 an average influent Chemical Oxidation Demand of 890 mg/l. At all the phases of HRT the first two compartments, the VFA concentration was higher due to the acid accumulation in the reactor and dampen pH level that inhibits the hydrolysis and acidogenic phase. Declined level of pH 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 methanogenic community for metabolism was hampered due to the lower level of pH in the first two compartments viz 6.7 and 5.9. The minimum COD removal efficiency and biogas production was attained in the first two compartments. The maximum percentage COD removal efficiency was achieved at 94.25% with a HRT of 5.0 days in the final compartment. The incremental range of pH in the fourth and fifth compartment indicated that the metabolism process was in methanogenic state. The results of this experimental study showed the intense effect on VFA synthesis in the AMBR..

Index Terms— Acidogenesis, Anaerobic migrating blanket reactor, Chemical Oxidation Demand, Hydraulic Retention Time, Methanogenesis, pH, Volatile fatty acids.

I. INTRODUCTION

With the improvement of world economic condition, water resources are becoming increasingly deficient and the quality 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 (Abdullah et al., 2005; Saktaywin et al., 2005; Sato et al., 2006). The high-rate anaerobic processes could be achieved by separation between the hydraulic retention time (HRT) and the solid retention time (SRT) (Pol et al., 2004). 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 (Zakkour et al., 2001).

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 (Wang et al., 2004; Krishna et al., 2007). The significant advantage of the ABR is its ability to separate acidogenesis and methanogenesis longitudinally down the reactor (Barber and Stuckey, 1999; Plumb et al., 2001; Uyanik et al., 2002a). This can permit different bacterial population to dominate each compartment, acidification predominating in the first compartment section and methanogenesis dominant in the subsequent section (Barber and Stuckey, 1999; Plumb and Stuckey, 2001; Uyanik et al., 2002b). A review paper on ABR was published in 1999. From then on, despite the ever-increasing number of publications on ABR in the last decade, there has never been any attempt to collect all the information in a review. Hence, the main objectives of the paper are to summarize some of the developments and applications of ABR and to provide useful information on their most important features. An overview of several recent studies has been reported in this literature, with the performance and characteristics of ABR described or analyzed and compared. To do so, an extensive list of recent literature has been compiled. Modeling of ABR, combination of ABR

Revised Manuscript Received on 14 February, 2019.

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with other processes are presented and discussed. The review also summarizes the application of ABR onpilot scale, which is important to determine the application of ABR on full scale. Compared with the paper published in 1999, this paper added many valuable literatures and demonstrated a worth review on ABR.

In India, there are lots of research Institutes and laboratories. In recent times, Institutional wastewater has become a matter of concern because of its potential hazardous effect. A satisfactory level of study to minimize this problem is yet to be reached because of various limitations. The raw Institutional wastewater contains various toxic organic and inorganic compounds, chemicals, pathogenic microorganisms etc. If they are released into the environment without any treatment, our natural water bodies will be severely affected by them. For this, the wastewater must be treated before releasing into the environment. The treatment includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. The content of the wastewater can vary, but the main characteristics are: Turbidity, pH, Total solids, Chemical Oxygen Demand (COD), Chlorides, Biochemical Oxygen Demand (BOD), Dissolved Oxygen. This research article focused mainly on impact of volatile fatty acid generation for the treating institutional wastewater.

II. EXPERIMENTAL METHODOLOGY

The present research work is to be carried out to evaluate the performance of anaerobic migrating blanket reactor for the removal of Institutional wastewater. The experimental model was fabricated by Plexiglass with a working volume of 68.25 litres. A proper construction of the baffles allowed wastewater to flow through the sludge bed from bottom up. The model has five compartments and the distance of the upper edge of baffles between the ascending and descending compartments from the water level was about 3cm. Three compartments are accomplished with suspended growth process and rest of the two are with attached growth process. The Bio carriers were filled randomly in the fourth and fifth compartment. The schematic of the experimental setup is shown in Figure 1. The photographic view of bio carriers is shown in Figure 2. and the product details of bio carriers were given in the Table 2. The physical features and processes parameters of experimental models presented in Table 1.

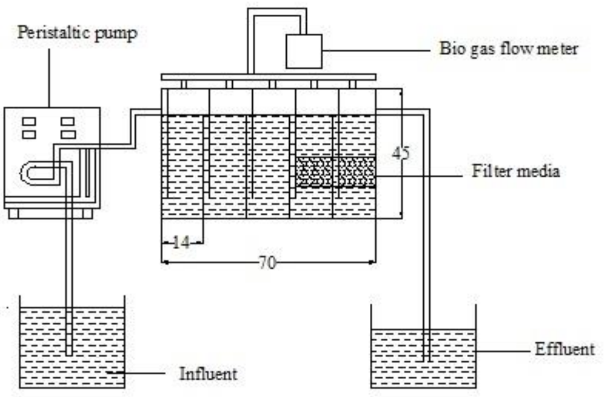

Figure.1. The schematic diagram of an Experimental setup

Table.1. The physical features and processes parameters of experimental models

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

Figure.2. The Photographic view of bio carriers

Table.2. Product details of Bio-carriers

Colour	Black
Model/Type	PP22
Size	15 x 22
Specific gravity	0.90 - 95 gms/sqcm
Density	0.93
Media fill Range	25 – 55
Structure	Cylindrical with external Fins
Surface area	400 sqm/cum
Diameter	22 mm
Height	15 mm
PSA/TSA ratio	75
Temperature	80^{0}C

III. RESULTS AND DISCUSSION

The reactor has been continuously operated at mesophilic range with an organic loading rate of 0.123 kg COD/m3.day during the start up period. The result showed that the AMBR attained a steady state from 18th day to 21st day. The low initial loading rate was recommended for the successful start-up of AMBR. 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 (Bhuvaneshwari et al., 2015). Prompt start-up is essential for the highly efficient operation of AMBR, due to slow growth rates of anaerobic microorganisms, especially methane producing bacteria. The COD reduction was attained 12% in the initial stage and it was incremental up to12th day and decline from 12th to 15th day and then attains a steady state from 18th day to 21st day. The maximum COD removal efficiency was achieved at 92.25%.

The pH is an important factor to control the digestion process in the anaerobic reactors. The methane forming microorganisms can survive in a condition with pH values ranging between 6.6 and 7.6 (Ritmann and Mc cardy P.L 2001)., although stability may be achieved in the formation of methane over a range of 6.0 to 8.0. pH values below 6.0 and above 8.3 should be avoided, as they can inhibit the methane forming microorganisms (Chernicharo C.A.L., 2007). The pH of the reactor was comparatively stable by varying from 6.8 to 8.3 which are well suited for methanogenic activities. This range of pH indicates that the reactor had sufficient alkanity to neutralize the organic acids delivered from the hydrolysis as well as the acidogenesis stages.

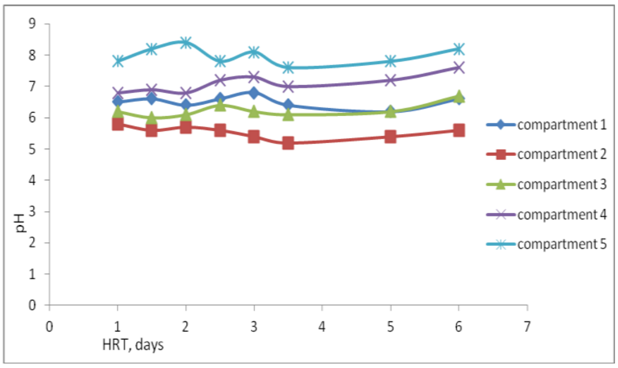

Figure 3: HRT, days VS pH

With the HRT of 6 days the pH falls from 6.21, 5.93, 6.50, 7.80 and 8.12 respectively in the compartments 1, 2, 3, 4 and 5. Normally once it reached a stable pH, the conditions of the pH will increase due to the formation of alkalinity. Load of the first compartment is the most severe because of the decrease in pH very sharp up to the second day. pH of the 2nd compartment was declined due to the growth of acidogenic populations (figure 3).

The high concentration of VFA during anaerobic process can inhibit the methanogenic activity.The pH level of each compartment was analysed. The influence of pH 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 an average influent Chemical Oxidation Demand of 890 mg/l. At all the phases of HRT the first two compartments, the VFA concentration was higher due to the acid accumulation in the reactor and dampen pH level that inhibits the hydrolysis and acidogenic phase. Declined level of pH 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 methanogenic community for metabolism was hampered due to the lower level of pH in the first two compartments viz 6.7 and 5.9. The minimum COD removal efficiency and biogas production was attained in the first two compartments. The maximum percentage COD removal efficiency was achieved at 94.25% with a HRT of 5.0 days in the final compartment. The incremental range of pH in the fourth and fifth compartment indicated that the metabolism process was in methanogenic state. The results of this experimental study showed the intense effect on VFA synthesis in the AMBR.

pH and VFA are the key parameters which affects both the treatment efficiency and the microbial community during anaerobic digestion process. Figure 3 shows the pH in each compartments under various operational conditions. In compartment 1 the ph from 6.2 to 6.8 during the experimental period. In compartment 2, the ph level was dropped from 5.2 to 5.8 due to the growth of acidogenic population. The ph of the compartment 3 was slightly incremental from 6.1 to 6.7 and further increased in compartment 4 from 6.8 to 7.6. Finally in compartment 5 the ph was from 7.6 to 8.4 due to the effective consumption of VFA. The relatively low ph is values from compartment 2 indicated that the wastewater was fermented to VFA by acetogens. The influent in the compartment 1 had hydrolysed to simple organics. This results demonstrated that the VFA (figure 4) had been converted to acetate and hydrogen gas by acetogens in the compartment (1,2), and these intermediates were then further converted to methane by methanogens in the subsequent compartments (3,4,5). The behaviour of the VFA concentration in the 5 compartments demonstrated that hydrolysis and acidogenesis were the important biochemical activities occurring in the first 2 compartments, whereas methanogenesis dominated in the last 2 compartments (figure 4).

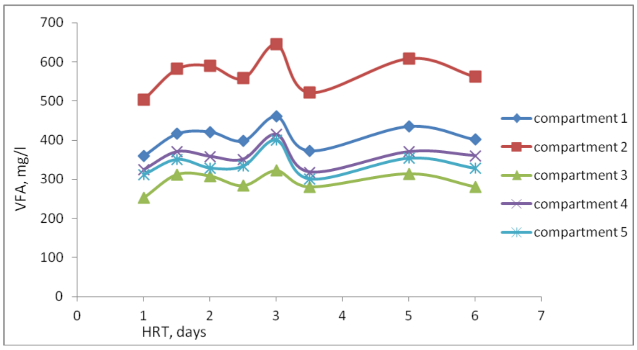

Figure 4: HRT, days Vs VFA, mg/l

The first compartment is the main reactor to decrease the organic content of wastewater, while for the removal efficiency of the second and third compartments was more significant, where the fourth and fifth compartment the COD removal efficiency was even more significant with 94.25%. The start-up stage of the process was began by continuous feeding of the reactor with an initial influent COD concentration of 890 mg/l with organic loading rate of 0.123Kg COD/m3/day. The COD removal rate during first two days was low in the range of 12% to 30%. The low

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efficiency in removal at the beginning of the process is due to the biomass adaptation to the new environment. The reactor achieved steady state condition during the period of 18th day to 21st day with a COD removal efficiency of 92.25% (Figure 5).

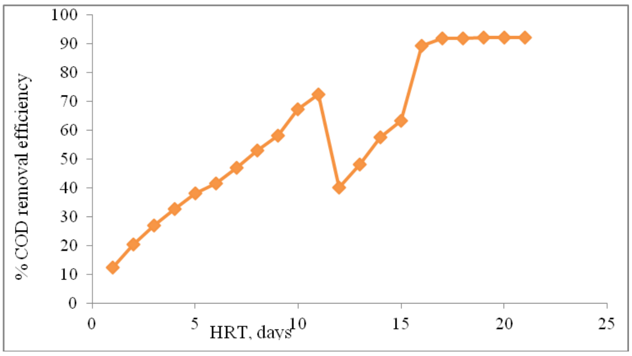

Figure 5: HRT, days Vs % COD removal efficiency

IV. CONCLUSION

This study reveals that the effect VFA concentration for the removal of organic substances in the institutional wastewater. The maximum VFA production was observed in the compartment 2 for the entire experimental study which may be due to the production of acidogenic organism in the compartment. The methanogenic population was in good performance in the fifth compartment. pH and VFA are the key parameters which affects both the treatment efficiency and microbial community. The Anaerobic Migrating Blanket Reactor configuration promotes the phase separation.

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