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ORIGINAL ARTICLE

Start-up regime in an Anaerobic Migrating Blanket Reactor for treating an Institutional Wastewater

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ABSTRACT
A laboratory scale Anaerobic Migrating Blanket Reactor was designed and fabricated for the treatment of Institutional wastewater. The Anaerobic migrating blanket reactor was accomplished with both suspended as well as an attached growth process. The reactor has been continuously operated at mesophilic range with an organic loading rate of 0.123 kg COD/m3.day. The result showed that the AMBR attained a steady state from 18th to 21st day. During the start-up period, the pH plays an important role in the decomposition of organic substances. The COD reduction was attained at 12% in the initial stage and was incremental up to 12th day and decline from 12th to 15th day and then attains a steady state from 18th to 21st day. The maximum COD removal efficiency was achieved at 92.25% with an OLR of 0.123 kg COD/m3.day at an HRT of 24 hours.
Keywords: *Anaerobic Migrating Blanket Reactor; Chemical Oxygen Demand; Institutional wastewater; Organic Loading Rate; pH.*

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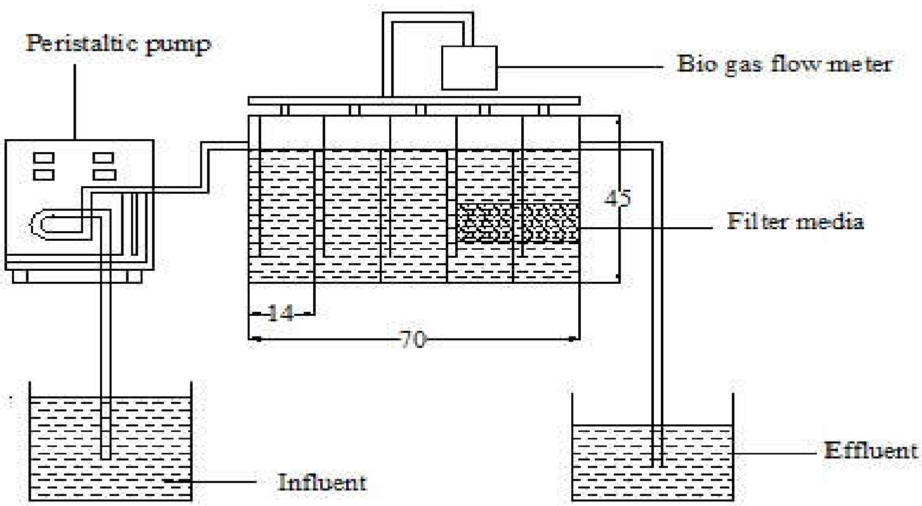
INTRODUCTION

Advantages of anaerobic pretreatment over aerobic treatment for low-strength wastewater include less sludge production and low energy requirements, which result in less operating costs [18]. Pretreatment of low-strength wastewater is more attractive under low-temperature conditions. Recently, several laboratory and pilot-scale studies revealed promising results for high-rate anaerobic treatment of low-strength wastewater at temperatures as low as 3 to 5°C [10, 16, 17, 20]. Most often an aerobic polishing (posttreatment) step is needed after the anaerobic system (pretreatment) to meet effluent quality standards, such as for effluent Nitrogen and Phosphorus levels [21]. For full-scale treatment of low-strength wastewater, the upflow anaerobic sludge blanket (UASB) reactor was mostly used [11, 17]. The UASB reactor consists of a single vessel with a hydraulic upflow pattern, and hence a gas–solids separator system and a feed-distribution system are required to retain biomass and to distribute influent evenly, respectively. Kato [13] showed in laboratory-scale studies that the expanded granular sludge bed (EGSB) reactor, which resembles a UASB reactor with a higher upflow velocity, was more efficient compared with the UASB reactor for this type of wastewater. Evidently, a higher mixing intensity in EGSB reactors because of a higher upflow velocity decreased transport diffusion limitations of substrate into the granules. Feasibility of this technology was confirmed with pilot-scale studies treating low strength malting wastewater at 13°C and 20°C [20]. Mechanically mixed, anaerobic sequencing batch reactors (ASBRs) were also thought to be an attractive option for the treatment of low-strength, low-temperature wastewater, because higher mixing conditions are combined with ideal conditions for biomass settling and retention in the reactor. In addition, because of the absence of a hydraulic upflow pattern, gas–solids separator and feed-distribution systems are superfluous, which simplified the reactor configuration compared with UASB and EGSB systems. Despite eliminating a hydraulic upflow pattern, the ASBR was able to develop and grow granular biomass [1-4, 23], which protects the strict anaerobes from oxygen toxicity in low-strength, low-temperature wastewater treatment [13]. An advantage of the ASBR technology was the alternating higher and lower substrate levels (feast and famine conditions) during the operating cycle, which resulted in increased biomass settling and retention before effluent decanting and increased substrate utilization rates just after feeding (Dague et al., 1998). Increased substrate utilization is preferred, as for lowstrength wastewater substrate utilization rates are generally low, dictated by Monod kinetics [19]. The kinetic advantage of relatively high substrate levels can also be obtained with a continuously fed staged reactor configuration, Lettinga *et al.* [16]. These researchers also found that staging was beneficial for the following reasons: (1) more favorable conditions for propionic acid degradation in the staged-reactor configuration because of low acetic acid and hydrogen levels in the second stage; and (2) relative high levels of bacteria in the first stage of the system (while methanogens were still present) and relative high levels of methanogens in the second stage (biomass staging), which improved biodegradation kinetics due to each major group of microorganisms existing in an optimal environment [15-17]. Another continuously fed staged reactor, the anaerobic migrating blanket reactor (AMBR) was developed, because there is still a need for simple and cost-effective high-rate anaerobic treatment systems for small and medium sized communities and industries, especially for treating low-strength wastewater [11]. The AMBR utilizes the advantages of the ASBR, such as mechanical mixing, biomass retention, a simple design (no gas–solids separation and feed-distribution systems required because of the absence of a hydraulic upflow pattern), and granulation [3]. In addition, the HRT in a continuously fed AMBR can be shortened (and thus the reactor volume can be decreased) compared with the batch-fed ASBR. Relatively long HRTs due to physical limitations of the system (a combination of a batch-fed operation and a relatively tall granular blanket) are required for the ASBR, because a reduction of the 6-hour HRT for ASBRs treating low-strength wastewater was not anticipated [10]. Because of the staged and continuously fed configuration of the AMBR (and thus a potential for short HRTs) in combination with a simple design, the feasibility of the AMBR system for the treatment of highly soluble, low-strength wastewater was studied. The AMBR treatment was evaluated under temperature conditions (30-35 °C) by monitoring reactor performance over a period of 6 months, during which the HRT was reduced from 144 hours to 24 hours in a stepwise manner. Biomass retention, granular size, and methanogenic activity of granules were also monitored during this period. In addition, a sudden drop of HRT from 24 hours to 1 hour was introduced to study the behavior of the AMBR under hydraulic- stress conditions, which are common for low-strength wastewater. The role of the anaerobic process has changed dramatically in wastewater treatment since the mid- 1980s. Its application for industrial wastewater treatment was classically preferred because of its low operating and maintenance costs. Yet, some major advantages could highlight its applicability. These are excess sludge reduction, energy recovery via biogas production, low requirements with respect to nutrients, high organic loading rates (OLR), and the possibility of toxic component biodegradation. The anaerobic baffled reactor (ABR) is known as high rate system and was initially developed in 1985. It was immediately attractive to researchers and operators, and introduced as a promising approach for municipal and industrial wastewater treatment [5]. The configuration of ABR is similar to a series of upflow anaerobic sludge blanket (UASB) reactors. However, it does not rely on granulated sludge forming, although granulation can occur over time [4]. Primarily, ABR has a variety of advantages in its configuration and maintenance, including its simplicity of design and mechanical equipment, relatively low hydraulic retention time (HRT) requirements, and high stability with respect to hydraulic, toxic and organic shock loads. Furthermore, the unique configuration of ABR may provide partial separation of acidogenic and methanogenic bacteria [6]. Recently, ABR has been successfully used for treatment of various wastewaters. These have come from a variety of sources, including domestic [14], distillery [1], soy bean protein processing, swine wastes [7], textile dyes, and heavy oil production [12]. It has also been studied as a pretreatment for different biological units like waste stabilization, and duckweed ponds. In addition its configuration has been upgraded by electrolytic enhancement methods, and by bamboo carriers, or modified for low strength municipal [9] and industrial wastewater similar to those from pulp and paper making. The Start-up performance of ABR treating textile wastewater at a continuous phase was attained a steady state from 75 to 78 days with an OLR of 0.252 kg COD/m^3.day [7, 8]. The anaerobic migrating blanket process is the most successful new anaerobic reactor design for various industrial and municipal wastewater (McCarty, 2001). It has become the most popular and widely used high-rate anaerobic wastewater treatment system worldwide [11, 13, 16], it was one of the anaerobic treatment systems that answered the urgent need for alternative treatment systems in view of increased environmental concerns amidst the energy crisis in the 1970s. Compared to other anaerobic treatment systems, it offers high chemical oxygen demand (COD) removal efficiency at shorter retention times, small land area requirement, low construction cost, simple operation and minimal pumping requirement [22]. Its ability to retain high biomass concentrations in the reactor is its key advantage. This research article envisaged the start-up regime of an AMBR for treating institutional wastewater.

MATERIAL AND METHODS

Experimental setup

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 the attached growth process. The Bio carriers (figure 2) were filled randomly in the fourth and fifth compartment. The product details of the bio carriers were given in the Table 1. The schematic of the experimental setup is shown in Figure 1.



Units: All dimensions are in cm.

Figure 1. The schematic diagram of an Experimental setup

Figure.2. The Photographic view of bio carriers

Table.1. 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	80^0C

Anaerobic Migrating Blanket Reactor. The AMBR, with a working volume of 72.25 L was divided into five compartments (Figure 1). The physical features of the reactor is given in the Table 2. Baffles between the compartments were used to reduce short-circuiting of substrate and shock load. The space between a baffle and the inside wall was 14 cm to prevent clogging by large granules. The experiment was undertaken in mesophilic range. Sufficient contact between substrate and biomass was maintained using intermittent, gentle mixing. Characteristic of a high rate system, the AMBR system hinges on a sludge retention mechanism in order to maintain contact between the wastewater and a high concentration of active bacterial mass. The AMBR reactor operates on the principles of an effective separation of the biogas, the liquid and sludge, formation of an easily settle able anaerobic sludge, and even distribution of raw waste over the bottom of the reactor. Influent wastewater is introduced from the top of the reactor, through evenly distributed nozzles. The sludge bed at the bottom of the reactor is the active bacterial mass that digests the organic pollutants in the wastewater. Production of biogas that resulted from the anaerobic digestion process induces mixing in the sludge blanket. Dispersed sludge particles are separated from the liquid, while the liquid leaves the reactor via the effluent line and the gas through the top of the reactor. In practice, start-up procedures vary in terms of loading applied. While it has been proven that seed sludge is not required for the start-up of an AMBR reactor treating sewage, its application will shorten the start-up time, which can take three to four months [22]. This paper reports the approach taken in starting up an AMBR reactor to be developed to treat institutional wastewater. Its performance during the initial stage of start-up will be presented and relevant observations highlighted.

Table. 2. 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

Start-up Procedure

In this research, a more flexible approach was adopted. The start-up strategy employed was to fill up about 100% of the reactor working volume. Institutional wastewater of approximately 0.123 kg COD/m^3/day was fed into the reactor by batch every three days. This was to avoid wastage of chemicals while the biomass acclimatise itself to the waste and multiply. The waste consisted mainly of acetic acid, propionic acid, n-butyric acid and glucose, supplemented with nutrients and trace metals. Stock solution with concentration of 220g COD/l was prepared. Dilutions to 0.123 kg COD/m^3/day were made using tap water before the institutional wastewater was fed into the reactor. The first batches of institutional wastewater fed immediately subsequent volumes fed ranged from approximately 0.5 – 1.0 kg COD/m^3/day per batch. The feeding of institutional wastewater would be switched to continuous mode once the biomass is acclimatised and growing well, characterised by stable biogas production. Initially, continuous pumping of feed would be at the lowest flow rate. Once COD removal reaches 90% or more, the flow rate would be increased stepwise by 10% or 5 rpm, whichever the higher. The reactor start-up initiation was accomplished over a period of 6 days. After about 4 months, no obvious biogas production was observed, other than some frothing on the top water level of the wastewater body. The influent and effluent pH, temperature and COD were determined periodically, and biogas production was monitored. The pumping rate of waste was increased when COD removal increased. The frequency of analysis was increased when gas produced was quantifiable. It should be noted that throughout the duration of the experiment during the continuous feed mode, frequent feed interruptions occurred due to various reasons such as power failures, maintenance works on the reactor e.g. unclogging of tubing, troubleshooting and modifications of the experimental setup to improve data collection, and other unavoidable circumstances in the laboratory. The duration of interruptions varied from a few minutes to about 50 hours.

Analytical Methods

The institutional wastewater was collected from the Annamalai University wastewater pumping station. The samples were characterized according to the protocol of Standard Methods [2]. Biogas was collected by gas flow meter. Gas volume readings were recorded not less than four hours after the start of collection.

RESULTS AND DISCUSSION

The influent and effluent samples from the reactor were collected once in three days and were analyzed immediately. Initially, the influent was collected from the treatment facility at Annamalai University and feed to the reactor with a COD of 780 mg/l with an OLR of 0.123 Kg COD/m^3.d. 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. Prompt start-up is essential for the highly efficient operation of AMBR, due to slow growth rates of anaerobic microorganisms, especially Methane producing bacteria.

During the first five days of the reactor startup (with domestic sludge), only frothing was observed on the surface of the wastewater body. This may indicate some respiratory activity within the reactor, but it did not result in noticeable biogas production. Minimal movements of sludge in the reactor could only be perceived over a considerably long period, e.g. a day. These were deduced from shifts in positions of coloured 'particles' suspended in the wastewater body. On the 8th day, a layer of sludge was observed on the top water level of the wastewater below the bubbles. These are presumed to be inactive biomass, which floated to the top. Over time, this sludge layer accumulated. Overall, the start-up process was either exceedingly slow, or not progressing well. Upto 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 VFA 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 3 shows the Influent COD and Effluent COD and the figure 4 shows the COD removal efficiency.

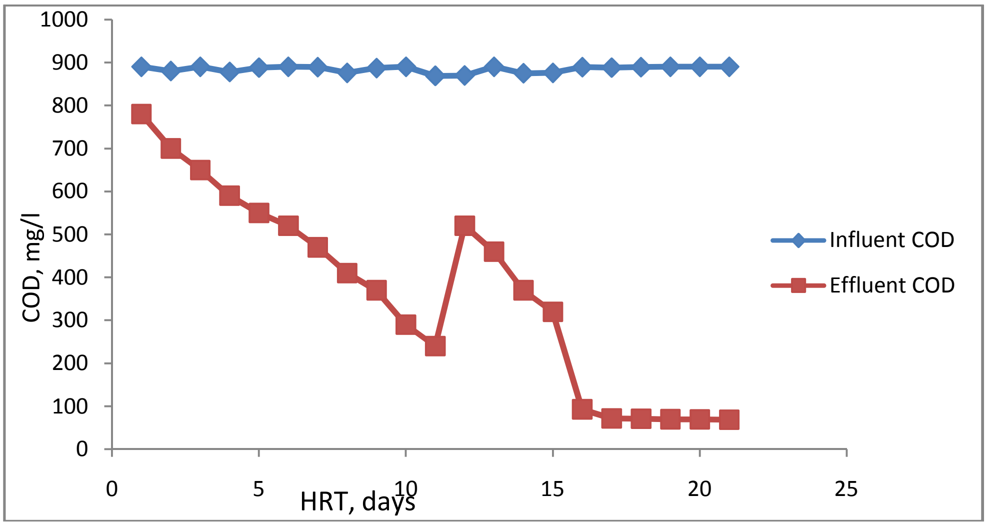


Figure. 3. HRT, days Vs Influent COD and Effluent COD during start up process

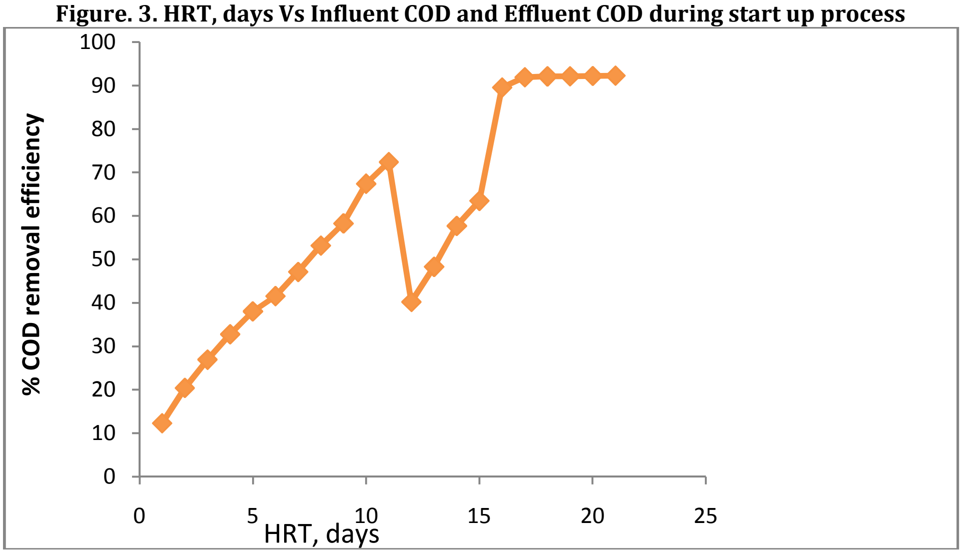


Figure. 4. HRT, days Vs % COD removal efficiency during start up process

pH

Figure 5 shows the pH in each compartments of the reactor. The effluent pH, which reflects the pH in the reactor, lies between 7.97 and 8.12. The maximum pH recorded is higher than the optimum pH for anaerobic digestion cited in most references, i.e. 6.5 – 7.5. However, from Figure 4, this did not affect the COD removal efficiency, which remained high at above 90%. Influent pH ranged from 6.2 to 6.8, although the pH prior to feeding to the influent tank was near to 7.0. The pH in the compartment 1,2,3,4 and 5 were observed as 6.21, 5.93, 6.50, 7.80 and 8.12 respectively during the start-up process. Both influent and effluent temperatures were well within the mesophilic temperature range of 20 – 40°C.

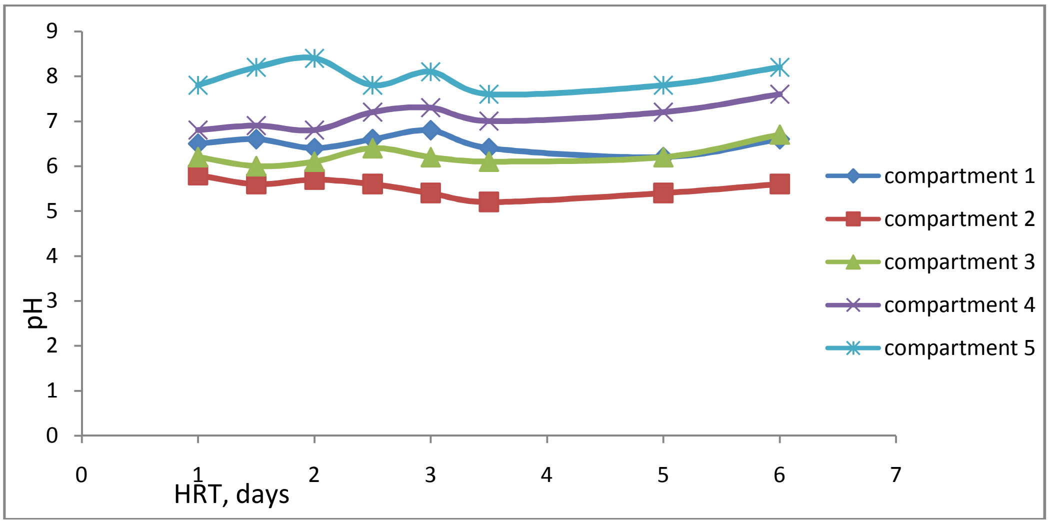


Figure. 5. HRT, days Vs pH during start up process

Biogas production

Despite the consistent bubbling observed in the wastewater body and phase separator during the period described earlier, no readings were registered in the gas flow meter. From Figure 5, biogas production was not constant and stable, despite the constant and high COD removal. This may be due to loss of gas through dissolution in the effluent and desorption of methane at the water surface. Losses between 20 and 50 per cent of the produced biogas are common [22]. This could also be an indication that part of the substrate digested was still used to synthesise new cells, as the reactor is still considered to be in its start-up stage. 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 m3 of biogas per kg COD removed was observed in this study (Figure 6).

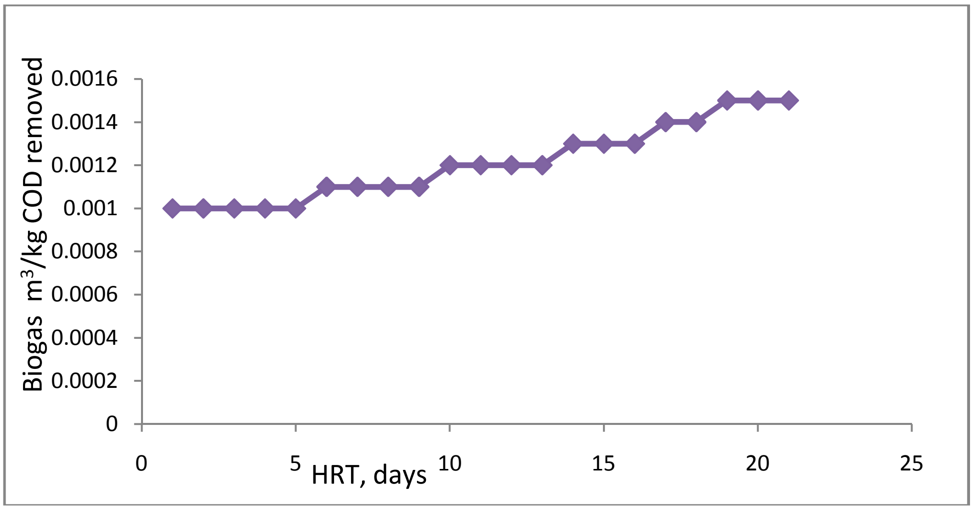


Figure. 6. HRT, days Vs Biogas

CONCLUSIONS

A laboratory-scale AMBR was fed with an institutional wastewater at an average COD concentration of 780 mg/l in a mesophilic range of temperature. Start-up is often considered to be the most unstable and difficult phase in anaerobic digestion. The result showed that the AMBR attained at a steady state from 18th to 21st day. During the start up period the pH plays an important role. 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 attain a steady state from 18th day to 21st day. The maximum COD removal efficiency was achieved at 92.25% with an OLR of 0.123 kg COD removed. The maximum biogas production was achieved at 0.0016 m^3 gas/ kg COD removed.

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