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Enrichment of Expanded Granular Sludge Bed Reactor during Start-Up Phase

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Abstract: ***The start-up period in anaerobic treatment process is generally measured as the period engaged for stable operation to be attained. A 14.47 litres working volume of bench scale anaerobic Expended Granular Sludge Bed Reactor was designed and fabricated for the treatment of slaughter house wastewater. The reactor has been continuously operated at mesophilic range with an organic loading rate from 0.013 to 0.014 kg COD/m^3.day with an Influent COD of 592 to 648 mg/l during start-up process with a HRT of 3 days. In anaerobic treatment process the main complexity to develop most suitable microbial culture in the reactor in terms of the granular formation and establishment of biomass. Throughout 70 days of continuous monitoring of the reactor, it was found that the Expended Granular Sludge Bed Reactor was attained a steady state from 54th day to 61th day with maximum of 91.14% removal efficiency during start-up phase. During the start up period Volatile Fatty Acid accumulation was also observed from 18th day to 27th day. The pH level also declined at these stages.***

Keywords: COD, Expended Granular Sludge Bed Reactor, pH, Mesophilic, Organic Loading Rate, Slaughterhouse wastewater, Volatile Fatty Acid.

I. INTRODUCTION

To fulfil the demands of domestic consumers, there are about 4,000 registered slaughter houses with the local bodies and more than 25,000 unregistered premises in India for slaughtering the animals. The fractions of organic matter to the slaughterhouse effluents are fat, paunch, protein, feces, grease, fat, and lard, undigested foods, blood, suspended material, urine, loose meat, excrement, grit and colloidal particles. The wastewater contains high concentration of suspended solid (SS), oil and grease, hair, and non-biodegradable materials. The untreated disposal of Slaughterhouse wastewater is one of the reasons for de-oxygenation of river and groundwater pollution[4 &5].

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The untreated Slaughterhouse Wastewater discharged into the environment poses various damage to the society, hence it require significant treatment for a safe and sustainable release to the environment [3 & 12]. Most of the researchers analysed the treatment practice of slaughter house wastewater with the support of different methodology [2, 11, 6]. Hamdy Seif and Amal Moursy[7] discussed treatment of slaughterhouse wastes and achieved removal efficiency of COD, PO_4 and NH_4were in the range of 77-96%, 65-84% and 31-52% respectively.

Rjakumar et al.,[15] studied treatment of poultry slaughterhouse wastewater in an up-flow anaerobic filter under low up-flow velocity with a maximum total chemical oxidation demand removal efficiency of 78 % at an organic loading rate of 10.05 kg/m3/day with an hydraulic retention time of 12 h. Wastewater discharged from slaughterhouses and meet processing industries has been classified by EPA as the most harmful to the environment.

Numerous researchers investigated about the methods of treating slaughterhouse wastewater by using several technologies such as anaerobic sequencing batch reactor [12], anaerobic-aerobic fixed-film reactor, up flow anaerobic sludge blanket reactors, coagulation-flocculation treatment and other technologies. Some characteristics of Upflow Anaerobic Sludge Blanket (UASB), Expanded Granular Sludge Bed Reactor[14], and Static Granular Bed Reactor(SGBR) were investigated in order to compare performance of the three phase recognize advantage and disadvantage respectively. Yoochataval et al[19] discussed that Characteristics of Granular Sludge in an EGSB Reactor for treating low Strength Wastewater. Seni Karchanawong and Wachara Phajee[16] discussed the effects of Upflow liquid velocity on performance of expanded granular sludge bed (EGSB) System. Anaerobic digestion in expanded granular sludge bed (EGSB) bioreactors has been proposed as a feasible low cost technology to treat high strength wastewaters, while biogas production from renewable resources could also be targeted[17 & 20]. Lettinga et al[10] analysed that the heavier sludge granules formed due to bacteria was retained during initial stages of start up process and the dead cells(lighter) are allowed to be washed out and also the washed out sludge should not be returned back to avoid the depression of the retained sludge. Many researchers focussed about the important features of startup stage, granulation in anaerobic treatment processes [9,1,8,18]. The core objective of the present research work is to examine the feasibility of start up stage of bench scale Expanded Granular Sludge Bed Reactor for treating slaughter house wastewater.

II. MATERIALS AND METHODS

This experimental study was carried out with an effective volume of 14.47 litres bench scale Expanded Granular Sludge Bed Reactor (EGSBR). The reactor was fabricated with Plexiglas including gas-solid separators (GSS). The entire research work was performed in the Research Laboratory at Department of Civil Engineering Annamalai University with a varied temperature from 28 to 42 ºC. The reactor has a column segment with a volume of 9.54 liters with gas-solid separators (GSS) part of 4.93 liters capacity.

The height and inside diameter of the cylinder column portion are 121.5 cm and 10 cm. The overall height of the reactor was 140cm with an external diameter of 20 cm. The specification with dimensions of the experimental setup is shown in Table .1. A variable speed of peristaltic pump (PP-10) was used to control the flow rate. A schematic diagram of an EGSB reactor is shown in Figure 1.

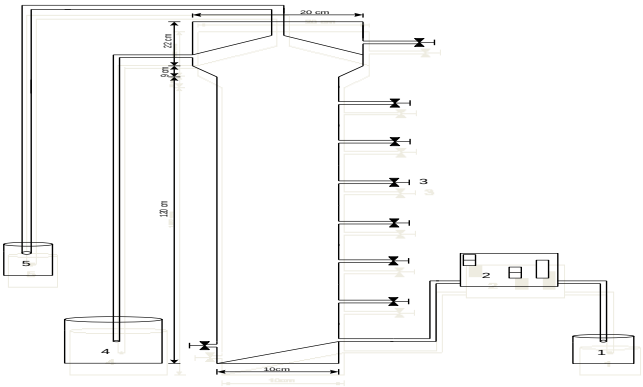

Fig. 1. Schematic of Anaerobic Expanded Granular sludge bed reactor

1. Influent tank
2. Peristaltic Pump
3. Sampling Ports
4. Effluent tank
5. Bio gas collecting jar

Table .1 Specifications and process parameters of experimental model

Specification	Dimensions
Total height of the reactor	152.5cm
Column portion	121.5cm
Diameter of the cylinder column	10cm
Triangle portion	9cm
Total liquid volume	14.47liters
Peristaltic pump	PP – 10 model
Free board	11cm

The EGSBR was inoculated with the granular sludge, which was collected from the active biomass plant located at Faculty of Agriculture, Annamalai University, Annamalai Nagar for acclimatization of the biomass. The overall objective of the start-up process was to establish the most suitable microbial population in the reactor. The slaughter house wastewater was collected from the market area of Chidambaram Municipality and were characterized (Table.2) as per the Standard procedure given in APHA [3]. The slaughter house wastewater composition varies according to the utilization of water in the market process and water demand. The organic pollutants present in the wastewater are in elevated level as compared to the desirable limits of IS 10500.

Table 2. Physiochemical Characterization of slaughter house wastewater

Sl. No.	Parameters	Raw wastewater	Desirable limit of IS 10500
1.	p^H	6.2	6.5 to 8.5
2.	Total solids, mg/l	3820	500
3.	Total dissolved solids, mg/l	2400	500
4.	Total Suspended solids, mg/l	1420	100
5.	Chemical oxygen demand(COD) ,mg/l	2080	250
6.	Biochemical oxygen demand(BOD_5),mg/l	1120	30
7.	Turbidity, NTU	31.5	10
8.	Phosphorous, mg/l	155	-
9.	Sodium, mg/l	680	200
10.	Potassium, mg/l	90	-
11.	Total Nitrogen, mg/l	480	100

III. RESULT AND DISCUSSIONS

Initially, the influent was collected from the treatment facility at Annamalai University and feed to the reactor with a COD from 592 to 648mg/l with an OLR of 0.013 to 0.014Kg COD/m^3.d. During start up the samples from inlet and out let of the reactor were collected with a HRT of 72hours and were analyzed immediately. Due to the slow growth rates of anaerobic microorganisms especially Methane producing bacteria, prompt start-up is essential for the anaerobic reactors. The EGSBR was operated in a continuous mode in a laboratory scale model with a effective volume of 14.47liters capacity to treat the organic pollutant in the slaughter house wastewater.

The start-up period is a crucial period for the stable operation of the EGSBR with a designed organic loading rate ranging from of 0.013 to 0.014Kg COD/m^3.d. In addition, operating temperature is prominent during start-up.

In this work, the EGSBR reactor, after seeding, was operated at a temperature between 28°C and 42°C, which is in Mesophilic range. The COD removal rate was in regular incremental from 3rd day to 15th day with an reduction rate of 17.14 to 60.86% but from 18th day to 27th day onwards the removal efficiency was declined from 38.46 to 54.54% due to the VFA production. At the declined level of COD removal rate the pH level was in lessening range (Figure. 2). The low removal efficiency at the initial stage of the start up process was due to the adaptation of biomass in the new surroundings, which can possibly be attributed to the presence of un adapted seed sludge in the reactor.

The COD conversion in the reactor was high and steady state from 54 to 61 days with a maximum COD removal efficiency of 91.14% (Figure .4.). The COD removal efficiency was fluctuated from 21st day to 48th day and then become a steady state from 54th day onwards. The COD level in the influent and effluent of the reactor was analysed and represented in Figure.3. The influent municipal wastewater pumped into the reactor was in an average range of 640mg/l of COD with a pH from 7.8 to 8.3.

The effluent pH during the start-up period is shown in **Figure 3.** The effluent pH value was from 5.8 to 8.2. The pH level in the reactor was sharply dropped at 27th day with an influent COD of 592mg/l, which may be due to the domination of acetogens in the reactor. The pH level was found to increase from 33rd day onwards and attained a steady state of pH 7.65. The results of pH related to this study indicated that the reactor with the Municipal wastewater have a good buffering system and non-inhibition of methanogenic organism during the start-up process. The biogas produced in the reactor was very minimum which may be due to the low strength of the municipal wastewater is 0.0017 to 0.0034 m^3 of biogas per kg COD removed. The biogas generated from the reactor was quantified by the method of water displacement and are shown in figure .5.

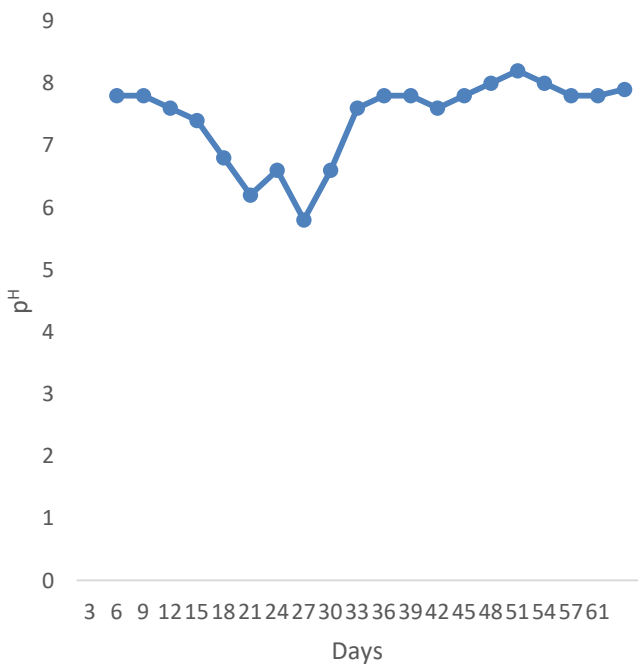

Figure. 2. Profile of p^H during start up process

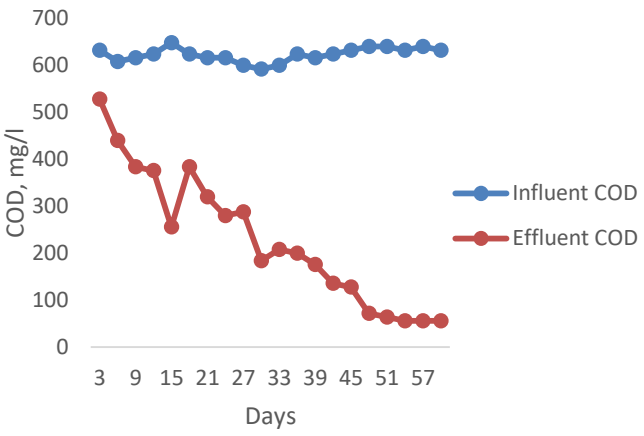

Figure. 3. Concentration of influent and effluent COD during start up process

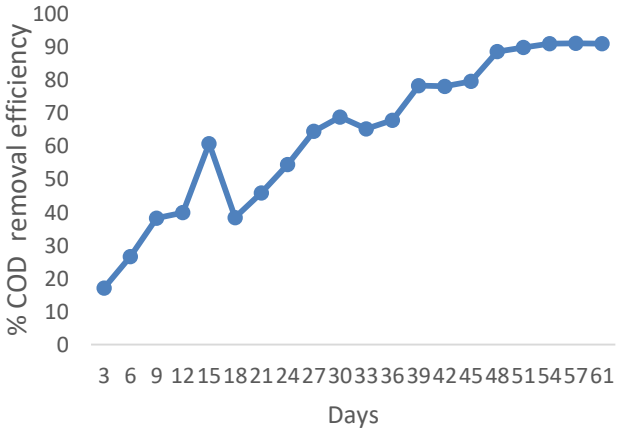

Figure. 4. Percentage COD removal efficiency during start up process

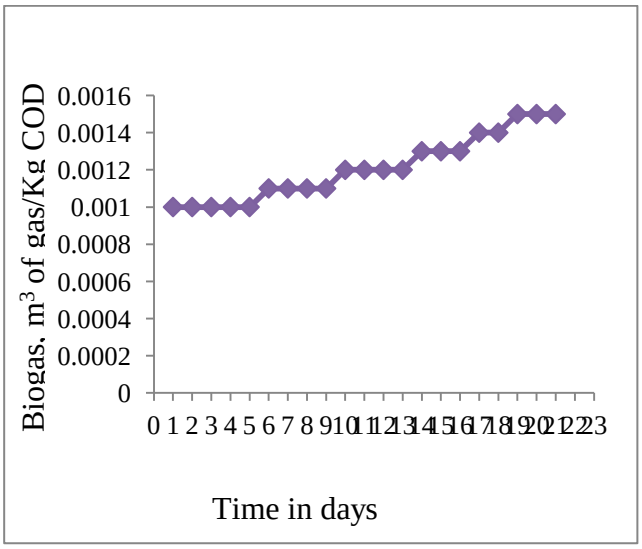

Figure. 5. Biogas production during start up process

IV. CONCLUSION

It is concluded that the Expended granular sludge bed reactor was achieved a maximum COD removal efficiency of 91.14% during start-up stage at an OLR of 0.014Kg COD/m^3.d. The pH level of the reactor plays an important role both in the treatment efficiency and generation of biogas. The reactor attains a stable COD reduction from 54th day to 61th day from start up. During the start up period VFA accumulation was also observed from 18th day to 27th day with declined level of pH. From the result of stability during start-up period, the removal efficiency of the reactor was satisfied and also able to apply higher organic loading rate for further degradation of slaughterhouse wastewater. During the start-up stage the biogas production was also estimated from 0.0017 to 0.0034 m^3 of biogas per kg COD removed. The results from the study indicated that the types of inoculums have a significant impact on the performance of the reactor start-up.

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