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Accelerated Granulation in Expanded Granular Sludge Bed (EGSB) Reactor Using Distillery Spent Wash with Chitosan and Aluminum sulphate

[G. M. Hiremath , Dr. Veena S.Soraganvi]

***Abstract*— Using distillery spent wash as a substrate, an experimental work was carried out with an intention to get accelerated granulation by Chitosan and Aluminum sulphate. Reactor was operated at a Sludge Loading Rate (SLR) of 0.687 kg COD/kg volatile suspended solids (VSS) per day, at an Organic Loading Rate (OLR) of 4 kg COD/m^3.d and Hydraulic Retention Time (HRT) of 12 hours. Granulation was achieved on 21st day VFA/ Alkalinity ratio had ranged from 0.2 to 0.48 . On 21st day, at an OLR of 12 kg COD/m^3/day, with COD removal efficiency of 82 % and methane production of 2.2 L/L day. Spherical granules of average diameter of 2.0 mm were observed. Thus both chitosan and Aluminum sulphate had a positive effect on the growth of granules.**

Keywords— **Organic Loading Rate , Hydraulic Retention Time, granulation, Expanded Granular Sludge Bed (EGSB).**

I. Introduction

In past three decades, concentrated efforts have been made to speed up anaerobic sludge granulation by addition of organic polymers, inert materials, cations and hybrid polymers. Under stressed loadings conditions, granulation occurred after 24-30 day of start-up (Joo et al., 2006). Most of these techniques have greatly reduced the start-up time. The addition of small amount granular biomass to non-granulated sludge had encouraged granulation process (Wang et al., 2007). EGSB reactors are currently used as anaerobic treatment systems and are attractive in respect of space and amount of waste to be treated by the industries (Fang et al., 2011a; Fang et al., 2011b; Liu et al., 2012; Scully et al., 2006; Zhang et al., 2008; Zupančič et al., 2012). Moletta (2005) showed the winery and distillery wastewater treatment by anaerobic digestion with the OLR of 5-15 kg COD / m^3 d and COD removal efficiency of high up to 90-95%. Granular sludge, has a higher specific methanogenic activity than flocculent sludge, which results in a larger conversion of waste to methane (Lamprecht C, 2009). Most authors identify the filamentous acetoclastic methanogenic species and Methanosaeta concilii are playing a major role in the development of the granule through a number of possible mechanisms (Foxon et al., 2010).

Mr. G. M. Hiremath
Associate Professor,Depatrment of Civil Engineering
Basaveshwar Engineering College , Bagalkot
India
Dr.Veena S . Sorgavi
Professor
Depatment of Civil Engineering
Basaveshwar Engineering College , Bagalkot
India

In this study, the natural polymer Chitosan is used as a booster for sludge granulation along with aluminum sulphate as flocculent. Thus combined effect can be observed on sludge granulation.

II. Material and Methods

A . Exprimetal set-up

The Schematic diagram of lab scale EGSB reactor is shown in Fig.1. The laboratory scale EGSB reactor was fabricated using 5 mm thick acrylic pipe with internal diameter of 50 mm, and overall height of 1350 mm. The reactor had a working volume of 2.4 L. The height of the reactor and gas-liquid-solid (GLS) separator were 1000 mm and 220 mm respectively. The upflow velocity is so set that it is sufficient to keep particles in fluidized state (4.0 m/ h). The provision of baffle arrangement was also made in the settler to guide the gas bubbles in to the separator, to capture the evolved gas and to allow the settling of suspended solids (Arne and Lettinga, 1992). Along the height of the reactor four sampling ports were provided at equal distance of 220 mm. The effluent flow line was 100 mm from top of the reactor. Methane production was measured with wet gas flow meter. The recirculation arrangement was provided to maintain the desired up flow velocities. Miclins (India) peristaltic pumps (Model PP 30 EX-2C and PP 60) were used for feeding and recirculation of the effluent respectively.

B. Inoculum

The reactor was inoculated with 0.8 L (33% volume of reactor) of non-granular anaerobic sludge obtained from UASB reactor used for treating sugar mill wastewater, active septic tank sludge and cow dung in ratio 1:1:1. The initial volatile suspended solid concentration was 19.39 g/L.

C. Substrate

Distillery spent wash used for the study was collected from Karthik Agro Industry, Bagalkot (INDIA).The analysis of all the parameters was done as per standard methods (APHA/AWWA/WEF, 1992). The characteristics of the wastewater are given Table 1.

Table 1. Characteristics of Distillery Spent wash Used for the Study

Parameters	Range
pH	3.95
Colour (unaided eye)	Chocolate
Dissolved solids	31655
Conductivity (µ- mhos/cm)	48700
Alkalinity (mg/L)	3488
COD (mg/L)	2,14.000-2,30,000
BOD (mg/L)	1,36,000
TC (mg/L)	80,670

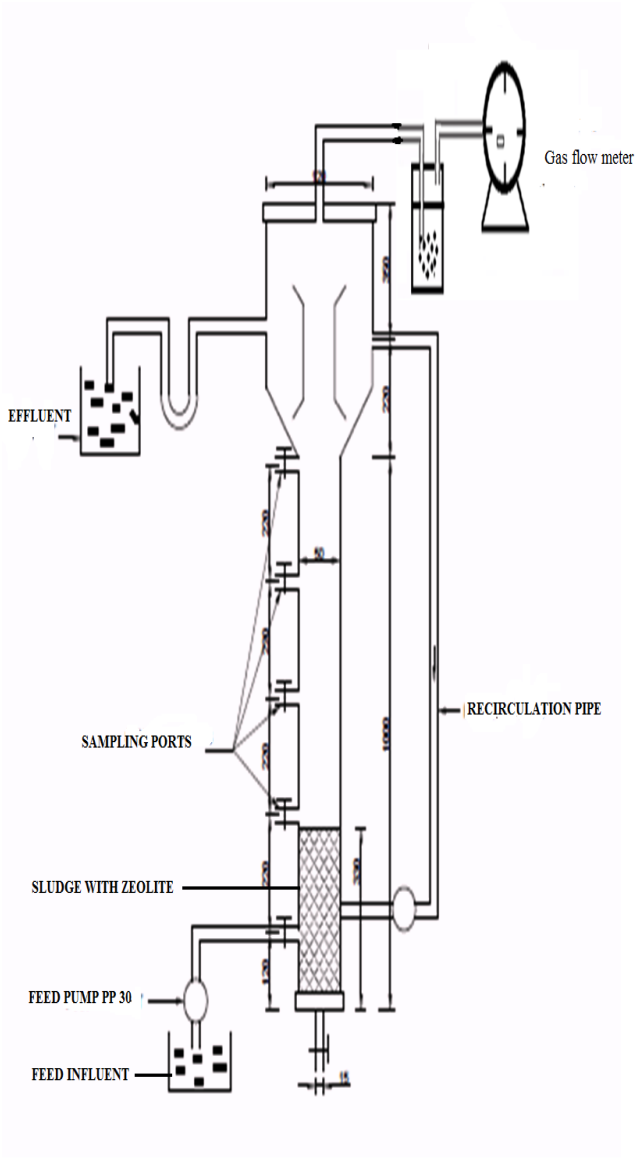

Fig.1 Schematic representation of EGSB reactor
(All dimensions are in mm)

D.Chitosan

Chitosan is a natural polysaccharide whose structure is similar to extracellular polymeric substances (ECP). ECP are widely known to assist anaerobic cell aggregation. Chitosan in liquid form was used as natural polymer achieved the enhanced sludge granulation of 2.0 mm diameter within short interval time of 21 days. The Chitosan added was 2 mg/gm of suspended solids.

E. Methanol

Methanol addition at start-up aided rapid biomass granulation. However, wash-out was severe and residual biomass was sensitive to methanol withdrawal and produced no net growth. Addition of methanol encouraged the growth of methanosarcina. Methanol addition is different for different concentration of feed.

F. Aluminium Sulphate

Aluminium Sulphate was added to increase the rate of anaerobic granulation. It acts as a flocculent. In this study addition of Aluminium Sulphate is 200 mg/L.

G. Analysis

Various parameters like pH, Alkalinity, Volatile Fatty Acids (VFA), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), biogas were analyzed as per standard methods (APHA/AWWA/WEF,1995).

H. Experimental procedure

The EGSB reactor was seeded with 0.8 litres of digested and screened sludge collected from an anaerobic digester of sugar mill industry, septic tank and cow dung in the ratio of 1:1:1 respectively. The wastewater was diluted to reduce the concentration of COD to 2000 mg/L and fed to EGSB reactor with initial HRT of 12 hrs. To start with, the reactor was operated at a Sludge Loading Rate (SLR) of 0.687 kg COD/kg VSS.d, at an organic loading rate (OLR) of 4 kg COD/m^3.d. The reactor was run for a period of 21 days. On the 1st day, with initial COD as 2000 mg/L, HRT as 12 hrs, OLR of 4 kg COD/m^3/day, COD removal efficiency was 10%. But as days progressed, on the 5th day the reactor showed COD removal efficiency of 79.5%. Then COD concentration was incremented to 3000 mg/L. On the 8th day, it was observed that COD removal efficiency reached 80.45%, then on 12th day and 15th day COD removal efficiencies reached up to 89.45% and 74.92% respectively. Likewise it continued, on 21st day it was observed that COD removal efficiency reached 82%.

The respective observations were made on effluent COD concentration, effluent pH, COD removal efficiency, effluent VFA, alkalinity, methane production by maintaining influent pH at 7. Every day analyses were carried out to know the effluent COD, effluent VFA, effluent alkalinity and measuring methane production. After that with influent COD and effluent COD value the COD removal efficiency was being calculated. Likewise VFA/Alkalinity values were in the range of 0.2-0.48.

III. Results and discussions

A. Granulation

The reactor was fed continuously with variable feed concentrations and COD removal efficiency was checked every day along with VFA and alkalinity ratio. Initially, the wastewater was diluted to reduce the concentration of COD to 2000 mg/L with an initial HRT of 12 hours which was kept constant throughout the study. The maximum loading capacity during the start-up was 12 kg COD/m^3/d. Daily observations were made on size of granules. On 13th day granules were of size 0.8 mm, on 21st day granules grew up to 2.0 mm.

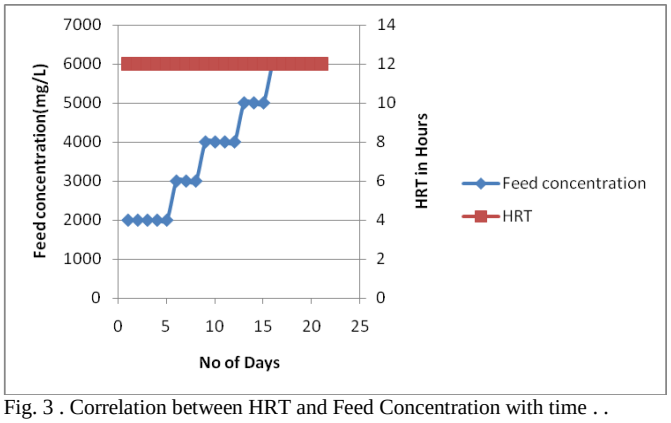

Fig. 3 . Correlation between HRT and Feed Concentration with time . .

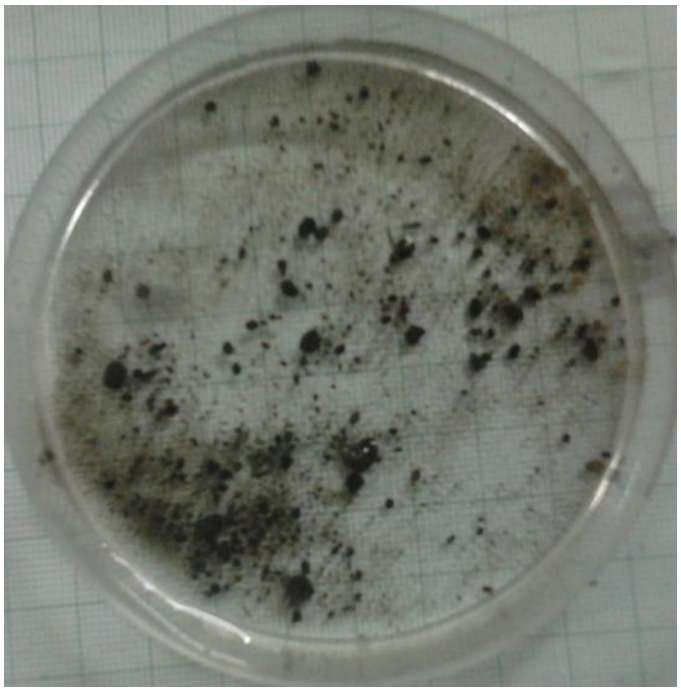

Fig. 2. Granules in EGSB reactor with chitosan

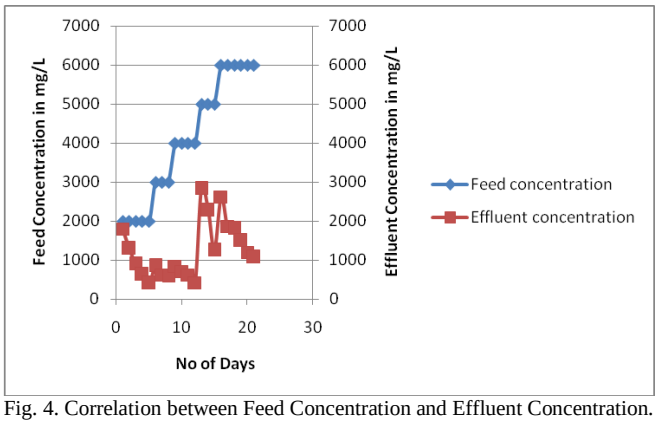

Fig. 4. Correlation between Feed Concentration and Effluent Concentration.

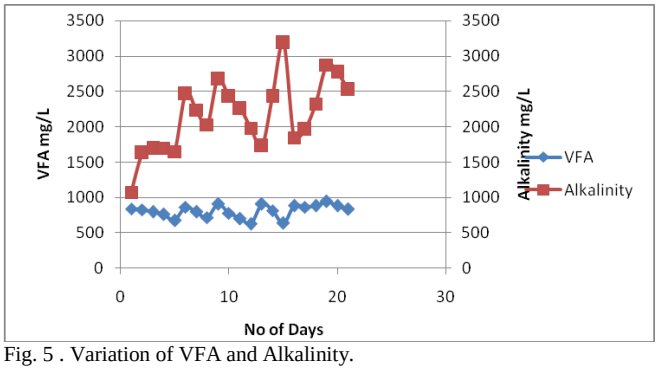

Fig. 5 . Variation of VFA and Alkalinity.

For EGSB reactor the granule development was determined by measurement of the average bioparticle diameter(d_{avg}). The average bioparticle diameter could be estimated using the equation.

$$d_{avg} = \sum d_i / n$$

where d_{avg} = Average bio particle diameter , d_i = Individual bio particle diameter , n= Number of bioparticles analysed.

$$d_{avg} = \frac{0.5+1+2+2+2+2.5+3+3}{8} = 2mm$$

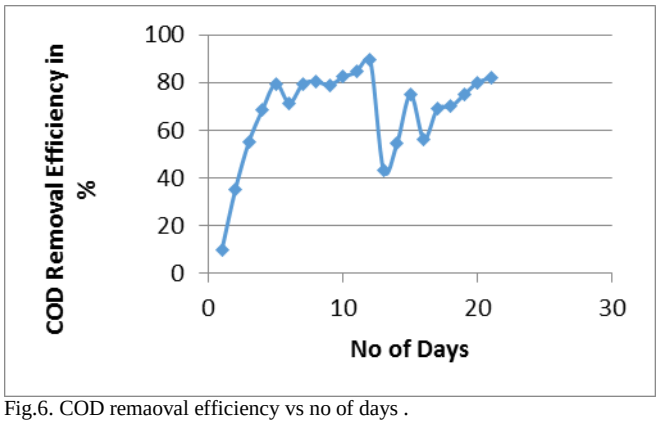

Fig.6. COD remaoval efficiency vs no of days .

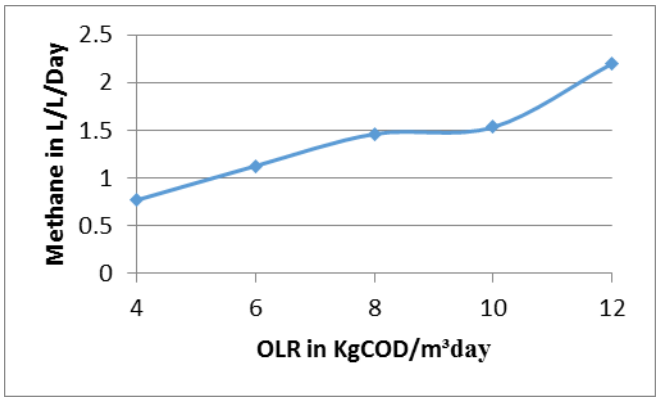

Fig.7. Methane production. vs OLR .

B. pH

The pH is an essential factor to be controlled during anaerobic digestion. The pH gradually increased and was in the range 7.6 to 8.1, which thus indicated the satisfactory condition of the reactor.

C. HRT and Feed Concentration

An initial feed concentration of 2000 mg/L was kept, which was progressed up to 6000 mg/L. Initially the Inoculum brought from sugar mill was capable of handling 4000 mg/L of COD. The HRT of 12 hours was kept constant from the start to till the end. Whenever the COD removal efficiency was satisfactory i.e., nearly 80% the feed concentration was increased from 2000 mg/L to 6000 mg/L in the increment of 1000 mg/L

D. Influent COD and Effluent COD

On the 1st day, with initial COD as 2000 mg/L, HRT as 12 hrs, OLR of 4 kg COD/m^3/day, COD removal efficiency was 10%. But as days progressed, on 5th day the reactor showed effluent COD of 410 mg/L. Then COD concentration was incremented to 3000 mg/L, on the 8th day, it was observed that COD was 586 mg/L. Likewise it continued, on 21st day for 6000 mg/L of influent COD it was observed that effluent COD was 1080 mg/L .

E. COD Removal

COD removal efficiency in the beginning was 10 % in the reactor. Influent COD was maintained 2000 mg/L until about 80 % of COD removal in the effluent was achieved. On the sixth day, COD was incremented to 3000 mg/L increasing OLR to 6 kg COD/m^3/day. COD removal efficiency drastically decreased from 79.5% to 71.4% in reactor. Like this on 21st day COD was 6000 mg/L at an OLR of 12 kg COD/m^3/day, with COD removal efficiency of 82 % for EGSB.

F. Methane Production

At an OLR of 4.0 kg COD/m^3/day EGSB showed methane production of 0.767 L/ L day. At the end of 21st day, at an OLR of 12 kg COD/m^3/day, it was 2.2 L/L day. An increase in OLR had positive effect on the methane production in the reactor. But VFA/Alkalinity ratio ranged from 0.2 to 0.48 but never came near 0.1 to 0.15

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IV. Conclusions

The performance of laboratory scale anaerobic EGSB reactor was investigated and compared for the treatment of distillery spent wash for different organic loading rates for a period of 21 days under mesophilic condition.

- When active non granular anaerobic sludge was fed as seed along with chitosan, beneficial effect was attained on granulation within a short period time of 21 days.
- Addition of polymer resulted in development of larger granules, higher methane production, and lower soluble COD in the effluent.
- EGSB reactor showed COD removal efficiency of 82 % for OLR of 12 Kg COD/m^3 day .
- Methane production in EGSB reactor was 0.767L/L/day at an OLR of 4 kg COD/m^3/day and 2.2 L/L/day at an OLR of 12 kg/COD/m^3/day.

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	Mr.G.M.Hiremath is an Associate Professor , Department of Civil Engineering in Basaveshwar Engg. College (autonomous)Bagalkot, India . He is a PhD Scholar working on waste water treatment process . His areas of interest are water and anaerobic waste water treatment.
	Dr.Veena S Soraganvi is Professor, Department of Civil Engineering in Basaveshwar Engg. College (autonomous)Bagalkot, India She is actively involved in research in wastewater treatment, groundwater flow and contaminant transport modeling and field studies, geo-environment, remote sensing and GIS applications etc.

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