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Treatment of Distillery Wastewater by Innovative Bio-MOD EGSB Process

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ABSTRACT

An innovative concept of expanded granular sludge bed reactor was developed and its performance evaluation for distillery wastewater was done. The study was performed in two stages. In first stage bio-degradability trial was performed to understand the pattern of organic removal in given environmental condition and to acclimatize the anaerobic culture with the constituents in wastewater. Based on results in first stage second stage continues trial was performed to evaluate the performance of expanded granular sludge process. Overall results shows that about 9 days were needed to acclimatize the culture in control environmental condition and reduce degradable organic carbon up to 90%. The results were further extrapolated in continues trial which also shows >90% removal of organic carbon at about 9 hrs HRT. The innovative design of settlers provided help to retain maximum sludge within anaerobic reactor and to get TSS free product. The study performed shows that EGSB process can be successfully applied to distillery wastewater for removal of organic pollutants.

Keywords: UASB, EGSB, settler, distillery, anaerobic, up-flow velocity, advance, bioMOD

INTRODUCTION

During last twenty years, anaerobic digestion processes for the treatment of wastewater experienced an important development. In this evolution, the UASB reactor has played an important role, becoming probably the most used alternative. In this reactor, a high sludge concentration is retained inside the reactor with simple and low cost equipment. This high sludge concentration allows the operation of the reactors under high organic loads. The EGSB (Expanded Granular Sludge Bed) reactoris aadvanced version of the traditional UASB (Up-flow Anaerobic Sludge Bed) technology. Both use granular sludge, but the EGSB reactor operates at high superficial velocities (1.5-6 m/h) (Medhat and Usama 2003; Estevao et al. 2013)

Traditionally, anaerobic digestion has been used for medium and high strength wastewaters which is having limitation of low velocity operation, effective contact between anaerobic culture and water, high HRT and larger foot print. In recent years, growing efforts have been applied in order to establish the feasibility of high rate anaerobic digestion, in the treatment of these effluents, and also for low strength wastewater. In a traditional UASB reactor this may result in channeling of the wastewater through the bed and therefore resulted in a poor water and sludge contact. The high superficial velocity of EGSB reactors enhance mass transfer rate. The EGSB reactor has shown to be not only suitable for the treatment of bio-degradable compounds, but can tolerate some presence of deterents. This is possible as it operates with high recirculation ratios, the feed is diluted to levels that the deterents are no longer inhibitory for bacterial activity. Superficial velocities have shown also to have an effect over size and activity of anaerobic granules (Estevao et al. 2013). As higher up flow velocities are applied in EGSB reactor, bed remains in more expanded condition (better mixed) and therefore it is possible to apply much higher volumetric loading (20 to 30 kg. COD/ m^3.day). Thus EGSB type of systems have smaller volume and smaller foot print than UASB systems. The present paper deals with design optimization of EGSB reactor, process operation and its application for successful treatment of distillery wastewater.

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Case study of treatability trials

In their run-up to the development of the technology, multiple trials were conducted with various high COD trials with effluent from various industries. One such trial in the distillery industrial space is brought out in the report presented as follows:

Specific case study in distillery

Objective: Maximizing reduction of BOD and COD from effluent from Distillery using EGSB technology

MATERIALS AND METHOD

EGSB reactor design

EGSB reactor is a variant of UASB concept for anaerobic wastewater treatment. The distinguishing feature is that a faster rate of upward-flow velocity, which is designed for the wastewater passing through the sludge bed. The increased flux permits partial expansion (fluidization) of the granular sludge bed, improving wastewater-sludge contact as well as enhancing segregation of small inactive suspended particle from the sludge bed. The increased flow velocity is accomplished either by utilizing tall reactors, or by incorporating an effluent recycle (or both). This causes high hydraulic mixing which improves the wastewater sludge contact (LIU et al. 2011; Cuadros Perez) biogas with a high concentration of methane produced as by-product. Captured energy source is used for generate electricity for export to cover its own running power. The technology needs constant monitoring when put into use to ensure that the sludge blanket is maintained, and not washed out (thereby losing the effect) (Lettiga 1995; Ramchandran) to maintain consistency of sludge bed within the reactor, Its very important to retain maximum sludge and restrict it from wash out. Reactor design play a key role in the process of sludge retention. BioMOD EGSB reactor is fitted with multiple settlers at different stages as per the character of sludge and separation solid, liquid and gas as per requirement of the process this also ensures retention of sludge blanket. The EGSB reactor made for laboratory testing was having 4.4 meter height and 100 millimeter diameter. The settlers are fitted at different location as shown in (Figure 1).

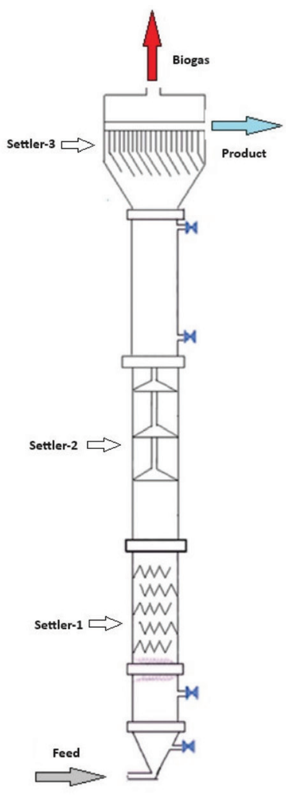

Figure 1 : Laboratory Testing EGSB Reactor

As shown in (Figure 1) wastewater enter from bottom of the reactor. Three different settlers are provided as internals to separate sludge, water and gas, roll of each separator is given below.

Settler-1: Vertical plates/tubes are inclined at 45^o to 60^o angle, certain gap between plates is maintained for flow of sludge and water. This incline plate/tubes provide surface to settle down heavy sludge and restricts those big particles to move out from the sludge bed. This settler installed at the bottom part of the reactor immediately above the thick sludge bed.

Settler-2: In this type of settler, incline perforated cones connected to centre pipe. Holes diameter and spacing is designed for effective separation of gas and liquid, biogas collected through central pipe is taken to the upward direction. This type of settler allows settling of the small sludge particles escaped from settler-1 and it helps in partial separation of gas from liquid.

Settler-3: Square shape three-phase separator used for separation of solid, liquid and gas at final stage. Combination of straight and inclined plates used to separate three phases in the reactor. All plates connected at top by square shape weir.

Image of actual BioMOD EGSB reactor is shown in (Figure 2).

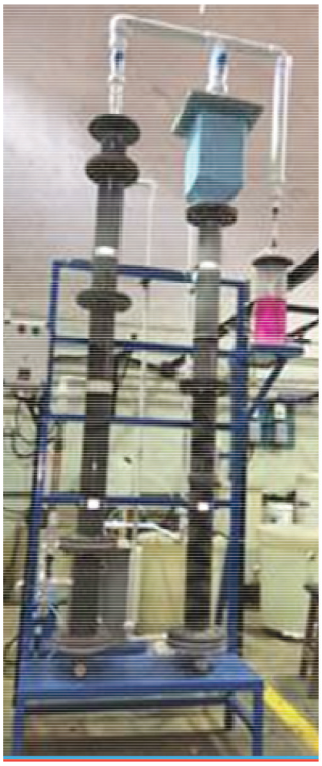

Figure 2 : Actual BioMOD EGSB reactor

Flow scheme of process operation:

The process performance of EGSB was studied under mesophilic condition (35oC +/-2 ^{0}C temperature range). Process flow scheme for EGSB study is as shown in Figure 3 below. Tank T2 which contains wastewater was enriched with necessary macro and micro nutrients through doing pump D3 enter to the mixing tank T1. The mixing tank was having provision of mixing to maintain uniform characteristics of feed water before it enter to the EGSB reactor. The mixed wastewater enter to the EGSB reactor by using pump P2, it passes through heater to maintain desired temperature. The EGSB reactor was insulated to avoid any loss of temperature during the operation. For the period of start up two chemical ferric chloride and poly-electrolyte were dosed along with feed water to initiate the process of granulation. After entering through bottom of the reactor, wastewater comes in contact with thick granulated sludge and the process of anaerobic digestion get initiated. Water keeps moving from bottom to top and separation of solid, liquid and gases takes place at respective zone of the settlers. Finally biogas exit from top of the reactor and treated water comes out from side port. Up-flow velocity was maintained in between 4 to 6 m/hr to keep the sludge bed in expanded form. The product water comes out further divided into two parts. One part as per flow scheme will go to product tank while another part recycle back to the mixing tank. The recycled water mixed with fresh feed water in mixing tank and feed to the EGSB reactor.

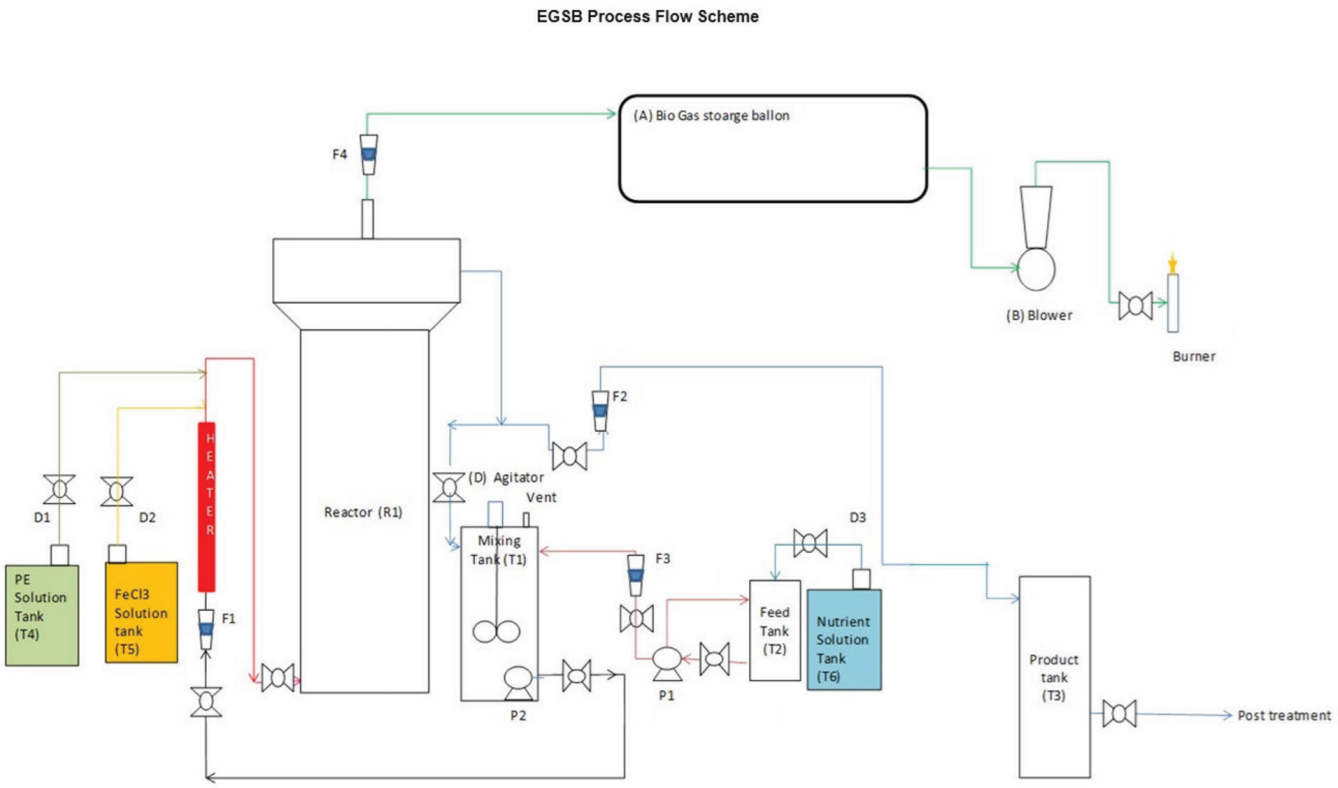

Figure 3 : EGSB process flow scheme

Treatability study of EGSB process performance with distillery wastewater

A treatability study for anaerobic digestion to understand the feasibility of utilizing EGSB process for distillery wastewater (condensate + spent less) was carried out. The wastewater was collected by nearby distillery with objective to perform test with real wastewater. The trial involves characterizing the wastewater, applying pre-treatment if necessary, and subjecting it to controlled anaerobic conditions. Parameters like, organic matter removal in the form of COD/BOD, ORP and pH were monitored. The trial aims to evaluate anaerobic digestion's performance, determining its potential as a wastewater treatment method and identifying any operational challenges. Table 1 shows detail analysis of wastewater received.

Anaerobic digestion is a biological process wherein microorganisms break down organic matter in the absence of oxygen, yielding biogas as a by-product. This process involves a sequence of reactions composed by various types of bacteria. Initially, complex organic compounds are converted into simpler molecules such as sugars, amino acids, and fatty acids. Subsequently, acido-genic bacteria convert these intermediates into volatile fatty acids, hydrogen, and carbon dioxide through fermentation. Finally, methanogenic archaea

Table 1 : Detail analysis of wastewater collected from distillery

Sr.	Parameter	Unit	Value
1	pH	-	2.72
2	TDS	mg/lit	256
3	TSS	mg/lit	27
4	COD	mg/lit	8000
5	BOD	mg/lit	5772
6	TAN	mg/lit	3.4
7	Nitrate	mg/lit	0.51
8	Nitrite	mg/lit	0.02
9	TKN	mg/lit	3.9
10	Silica	mg/lit	157
11	Alkalinity	mg/lit	Nil
13	O&G	mg/lit	2.8
14	Color	PtCo	53
15	Total Hardness as CaCO3	mg/lit	164
16	Calcium Hardness as CaCO3	mg/lit	160
17	Chloride as cl	mg/lit	212
18	Sulphate as SO_4	mg/lit	61

metabolize these compounds to produce methane and carbon dioxide, constituting biogas. This scientifically intricate process is governed by environmental factors like temperature, pH, and substrate composition, making anaerobic digestion a promising avenue for sustainable wastewater treatment due to its efficiency in organic matter removal and renewable energy generation.

RESULTS AND DISCUSSION

Batch mode trial

The study of distillery wastewater treatment through anaerobic process was divided into two stages. First stage consist of batch mode trial in which biological degradability was studied by monitoring of reduction of COD and BOD in controlled condition batch mode while in second stage continues operation in EGSB modes was carried out at certain HRT and operational condition. The study of first phase revelled that water is biologically degradable and extent at which COD and BOD can be reduced. This stage also help to produce acclimatized culture which was further utilized in continuous trial. In first stage trial feed water was added to the reactor only once along with the anaerobic culture and carbon reduction was monitored along with pH and ORP: condition of the reactor. (Table 2) shows details of stage-1 (batch mode trial) reactor condition along with analysis of COD and BOD at zero hour before initiation of the reaction.

Table 2 : Details of stage-1 trial

Sr.	Parameter	Value
1	COD (mg/L)	1900
2	BOD (mg/L)	1279
3	BOD:COD	0.67
4	MLSS (mg/L)	20540
5	MLVSS (mg/L)	10740
6	MLVSS: MLSS	0.52
7	COD contribution	40%
8	Anaerobic Sludge mass	60%
9	Incubation temperature	370C
10	pH condition maintained	6.8+/-2

Original COD of wastewater was 8000 mg/lit which reduced to 1900 mg/lit after addition of culture to initiate the anaerobic reaction. There was about 40% contribution of wastewater and 60% contribution of anaerobic culture to the total reactor volume. Initial COD was taken as reference point and further reduction was monitored subsequently. The results obtained in batch mode trial are tabulated in Table 3.

Table 3 : Results of batch mode trial

Day	pH	ORP (mV)	COD (mg/L)	% COD red.	BOD (mg/L)	% BOD red.
1	7.00	-165	1900	-	1279	-
2	7.19	-184	880	54	-	-
3	7.13	-196	850	55	346	73
4	7.34	-185	500	74	-	-
5	7.32	-181	440	77	-	-
6	7.30	-188	440	77	212	88
7	7.11	-193	320	83	197	89
8	7.22	-216	280	85	-	-
9	7.18	-209	140	93	92	95

As tabulated in (Table 1), there was gradual reduction of COD and BOD and reduction was achieved to >90% on 9th day of incubation. Reactor health in terms of ORP was also good which shows that true anaerobic condition was maintained in the reactor. Reduction of COD and BOD to >90% indicates that constituents in wastewater are showing response to biological degradation and culture supplied is also getting acclimatized to the wastewater environment and started utilize the biologically degraded organic compounds as food. The results obtained in batch mode trial are plotted in Figure 3 to show reduction of COD with time.

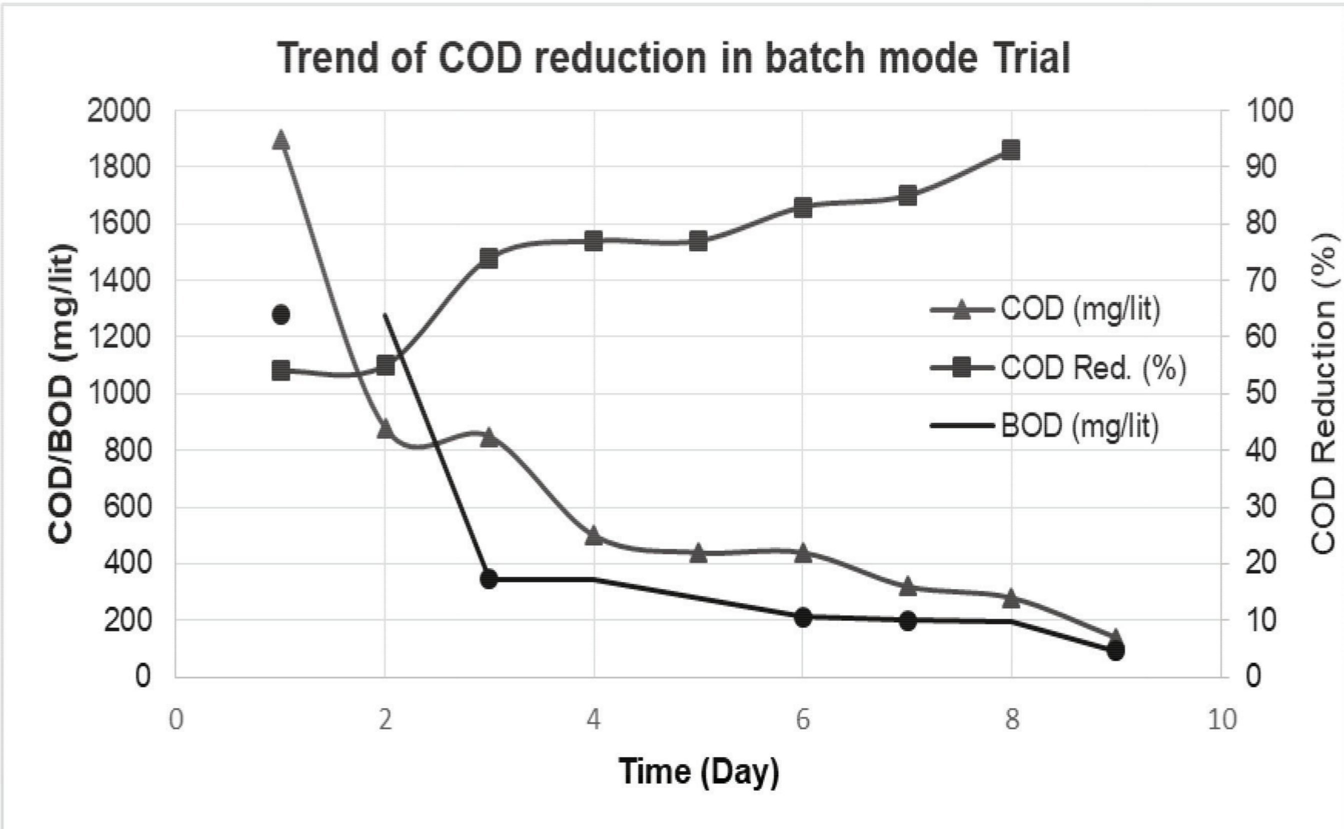

Figure 4 : Trend of COD reduction in batch mode trial

Continues mode trial

Continues mode trial was carried out in real operating condition. Total volume of the reactor used for trial was 35 lit. The sludge acclimatized in batch mode trial was used seed to initiate the continues trial. Use of acclimatized sludge provided the advantage of quick startup of the EGSB reactor and optimization of the process operation. Continues fresh addition was made to the bioreactor and process operation was carried out as the flow scheme shown in the (Figure 2). The operating conditions for continues operation are tabulated in Table 4.

The process was operated steadily to get consistent results. Reactor HRT was achieved by slowly ramp up of the operation with respect to gradual increase in up flow velocity. Initially the reactor was operated at higher HRT and low up flow velocity, with increase of up-flow velocity HRT also reduced, continues operation was carried out at 9 hrs HRT and 21kg. COD/m^3.day. This condition provide optimum process operation in terms of productivity and COD loading. Though EGSB can handle higher COD loading, it is the matter of constituents present in wastewater. The feed water having similar character as shown in Table 1. The results obtained during continues trial are shown in Table 5.

Table 4 : Operating condition for continues trial

Particular	Unit	Value
Total volume of the reactor	lit	35
MLSS mg/lit	20,000	
Reactor HRT	hrs	9
Reactor pH		6.90
Reactor ORP	mV	-205
Feed COD	mg/lit	8000
COD loading	Kg.COD/m^3.day	21

Table 5 : Results of continues trial

Day	COD (mg/lit)	COD Reduction (%)	BOD (mg/lit)	BOD Reduction (%)
1	680	92	-	-
2	720	91	314	95
3	790	90	-	-
4	750	90	-	-
5	795	90	-	-
6	810	89	483	92

The graphical representation of results obtained in given in (Figure 4).

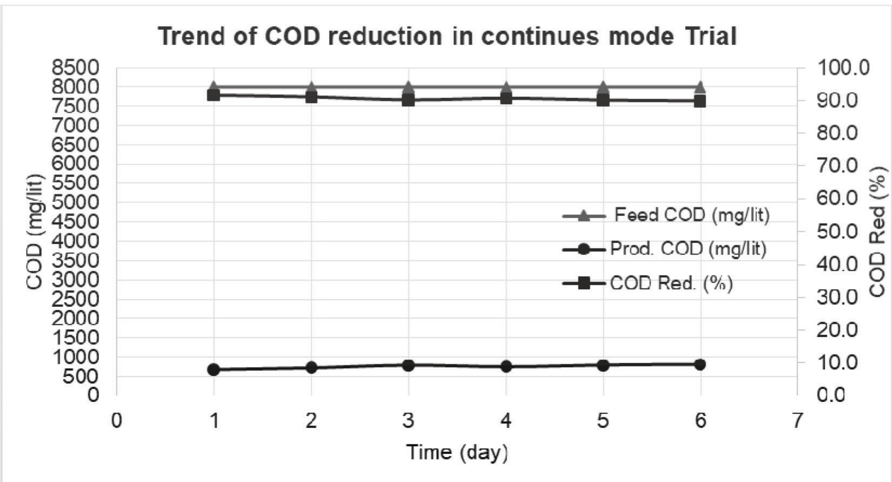

Figure 4 : Trend of COD reduction in continues mode trial

Continues trial shows consistent reduction and COD and BOD, this indicates that the culture acclimatized in batch trial is continue to show response towards degradation of organic compounds in wastewater. The results obtained indicates that EGSB process is appropriate choice for treatment of distillery wastewater.

Sludge properties

Sludge of EGSB reactor observed to very much granulated and settling property was very good. The images of sludge settling with respect to time is shown in Figure 5.

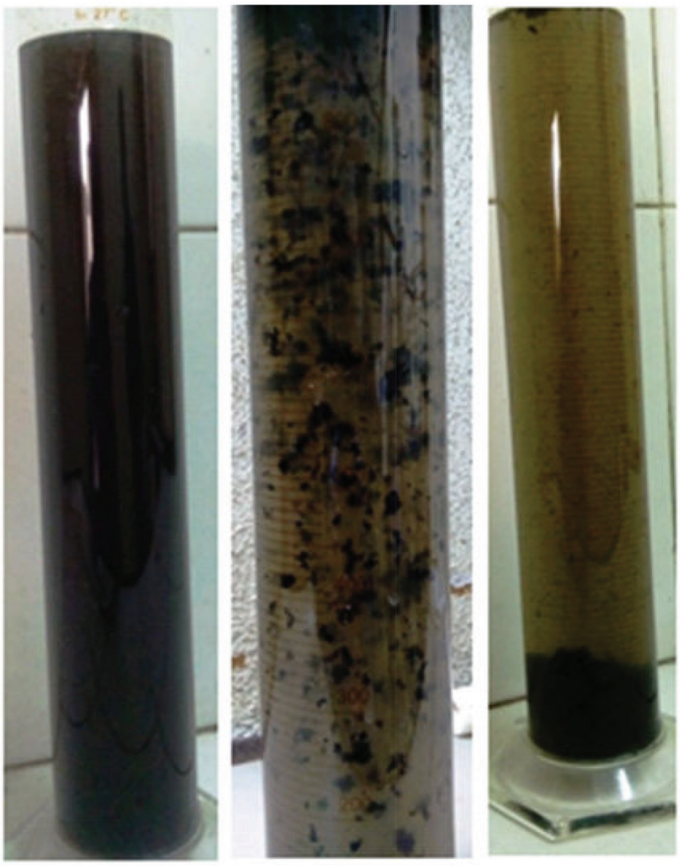

Figure 5 : Sludge settling images

Treated water quality

The combination of multiple settlers and process control in terms of up-flow velocity, COD loading, following right commissioning steps help to improve product quality in terms of lower TSS value. The sludge granulation help to remain maximum concentration of thick sludge at the bottom of the reactor, where wastewater immediately comes in contact for initiation of anaerobic digestion. Stage wise separation solids to TSS free product water is shown in (Figure 6).

With the efforts of sludge granulation and introduction of settlers, EGSB product turbidity was observed to be <30 NTU and TSS measure was <100 mg/lit.

The trials conducted demonstrated high success of the technology with respect to reduction of COD, BOD and also TSS levels.

Technology comparative

Based on our trials on various industry effluent and operating experience, we have established the following

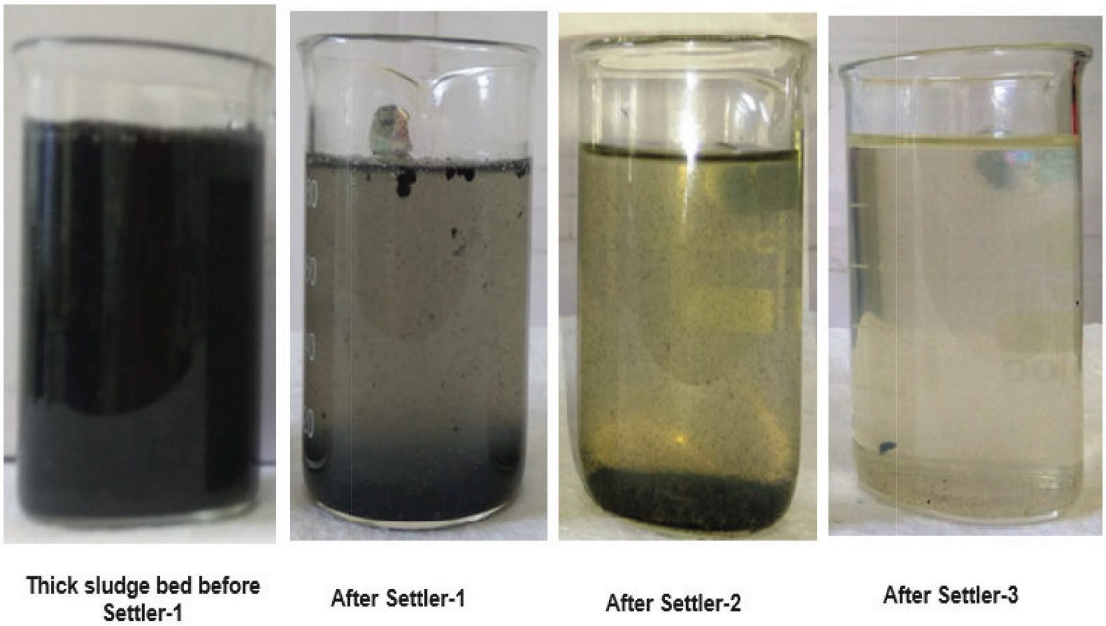

Figure 6 – Stage wise separation of TSS from EGSB reactor

Sr. No	Particular	UASB/Conventional Technology	BioMOD EGSB
1	Up-flow velocity	<1.5 m/hr	1.5 to 6.0 m/hr
2	Biomass type	Flocculent biomass	Granular biomass
3	Biomass cost	Low	Low
4	Commissioning period	50 to 60 days	30 to 45 days
5	Organic loading	5 to 7 kg.COD/m^3.day	15 to 25 kgCOD/m^3.day
6	Reactor volume	High	Low
7	Foot printHigh	Low	
8	COD Reduction	70 to 80%	70 to 90%
9	Biogas generation	0.3 to 0.35 m^3/kg.COD	0.3 to 0.35 m^3/kg.COD
10	Biomass liquid separation	Single separator	Three stage separator
11	Biomass washout chances	High	Very Low
12	Maintenance	Low	Negligible

comparison of UASB/conventional technology and BioMOD EGSB

CONCLUSION

Anaerobic digesters are increasingly adopted by industrial end users because they can treat both suspended and soluble COD and produce methane biofuel as a byproduct. Rising demand for high-capacity biological water treatment in distillery and ethanol plants in India and around the world has prompted a push for more efficient, compact, and cost-effective solutions. EGSB technology, with its scalable design, small footprint, rapid production, and advanced configuration, consistently delivers all of these benefits. BioMOD EGSB's proprietary multi-settler reactor design allows for exceptionally high sludge retention, resulting in energy-neutral or energy-positive process conditions as well as lower operational, post-treatment, and discharge costs. This technology provides clients with unique value due to its small footprint, maximum sludge retention, and high-purity biofuel production.

Few advanced features of this technology create the differentiators vis-à-vis conventional technology such as

- Innovative design of inclined cone settler successfully separates gas and liquid at middle stage and take it out from the EGSB reactor.
- Process control and internal reactor design help to obtain TSS free product quality and retain active culture within EGSB reactor.
- Retained sludge recycled back to the reactor, increases efficiency of the process.
- Study performed with distillery wastewater shows successful removal of biodegradable pollutants from wastewater by application of EGSB process. More than 90% COD and BOD reduction has been observed.
- It was observed that process can take COD loading up to 21 kg.COD/m^3.day at 9 hours HRT and deliver consistent reduction of COD and BOD.
- Overall study shows that EGSB process can be successfully applied to wastewater having biologically degradable organic compounds with TSS free product quality and optimum design and operating condition. It provide optimum design condition which can reduce foot print required and also reduces cost for post treatment required as per requirement of recycle and reuse.

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