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Treatment of spent wash in anaerobic mesophilic suspended growth reactor (AMSGR)

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Abstract : *Approximately 400 KL of spent wash or vinasse per annum is generated at an average COD concentration of 100,000 mg/l, by over 250 distilleries in India. There is an urgent need to develop, assess and use ecofriendly methods for the disposal of this high strength wastewater. Therefore, an attempt was made to investigate a few aspects of anaerobic digestion of spent wash collected from a distillery. The study was carried out in a 4 L laboratory scale anaerobic mesophilic suspended growth reactor. After the successful startup, the organic loading was increased stepwise to assess the performance of the reactor. During the study period, biogas generated was recorded and the maximum gas generated was found to be 16.9 L at an Organic Loading Rate (OLR) of 38 g COD/L. A 500% increase in the Volatile Fatty Acid (VFA) concentration (2150 mg/L) was observed, when the OLR was increased from 38 to 39 g COD/L. During the souring phase the removal of COD, Total Solids (TS) and Volatile Solids (VS) were in the order of 52%, 40% and 46% respectively. The methane content in the biogas varied from 65% to 75%.*

Key words : *Anaerobic digestion, Spent wash, Biogas.*

Introduction

Approximately 400 KL of spent wash or vinasse per annum is generated by over 250 distilleries in India (Ramachandra, 1999). It was estimated that about 15 litres of spent wash is discharged for every litre of alcohol produced (Kaul *et al*., 1994). The population equivalent of distillery effluent based on BOD load has been reported to be as high as 6.2 billion which means that contribution of distillery waste in India to organic pollution is approximately seven times more than the entire Indian population (Handa and Seth, 1990). No wonder distilleries are therefore considered as one of the most polluting industries in India. Spent wash with a COD of over 1,00,000 COD mg/L and BOD of 30,000 mg/L ranks high amongst the pollutants produced by industries both in magnitude and strength (Routh and Dhaneswar, 1986). Treatment and safe disposal of spent wash has been a challenge for a long time (Chao, 1983). The high strength of spent wash renders aerobic treatment, which is too expensive, and physico-chemical processes have met with little success (Shivayogimath and Ramanujam, 1999). Anaerobic treatment of spent wash is likely to ensure high degree of treatment and recovery of renewable resources. This approach is more attractive for developing in tropical countries like India, where temperatures are suitable for anaerobic digestion in most part of the country. In India, variety of anaerobic reactors including anaerobic lagoon (Suba Rao, 1980; Ilyas *et al*., 1998), conventional digester (Parthasarathy *et al*., 1967), anaerobic filter (Gadre and Godbole, 1986) and two staged fixed reactors (Kaul and Badrinath, 1984) have been studied. However no attempt has been made to evaluate the usefulness of AMSGR for treating spent wash. Hence the present study.

Materials and Methods

Distillery effluent for the present study was collected from Mohan Distillery and Brewery Ltd., Chennai, India. The samples were transported to the laboratory in polyethylene container and stored at 4ºC as recommended by Kostenberg and Marchaim (1993) until required.

Inoculation: The reactor was seeded with an inoculum (biogas slurry from active biogas plant) to about 30% of the reactor volume as recommended by Young and Mc Carty (1969) for a suspended growth anaerobic reactor. The characteristics of the inoculum used are shown in Table 1.

Fabrication and setting up of anaerobic digester: The schematic diagram of the laboratory scale digester used for the study is shown in Fig.1. A round bottom glass container of five-litre capacity with a working volume of 4L (Borosil make) was used as the digester. The mouth of the reactor was closed with a lid having three openings. Through one of the openings a glass tube was inserted to reach the bottom of the reactor. This served as the outlet for digested waste. Another tube inserted through the second opening served as the inlet for the feed. To facilitate the circulation of feed, a common tube was used to connect the outlet and inlet tubes. In the connecting tube provisions were made to place pH (Make : Elico, Model : LI 120) and temperature probes (Make : Amadigit, Model: ad 20). A peristaltic pump was used for circulating the feed. The third opening served as the outlet for gas. Through which a tube was connected to a wet gas meter (Make: Ritter, Model: TG1) for gas measurement. The entire experimental unit was made airtight by applying a chemical sealing agent (M-Seal manufactured by Mahindra and Mahindra Company, Pune, India).

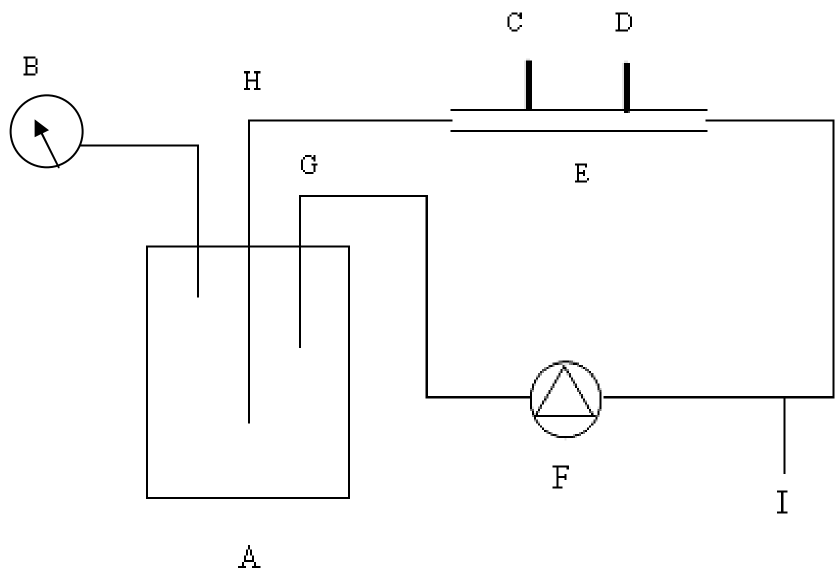

Fig. 1: Laboratory scale anaerobic mesophilic suspended growth reactor.
A- Digester; B- Wet gas meter; C- Ph probe; D- Digital thermometer; E- Connecting tube;
F- Peristaltic pump G- Sample inlet H- Sample outlet I- Sampling tube.

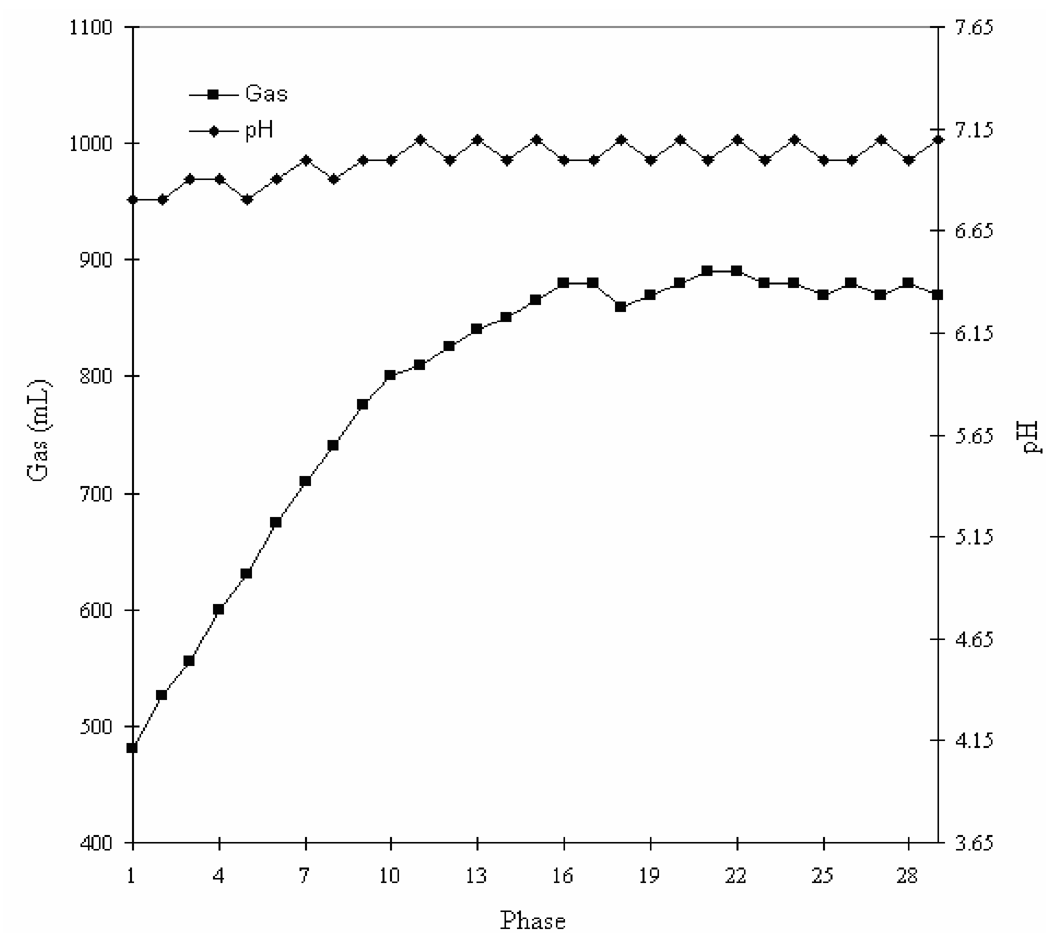

Fig. 2: Gas yield and pH variation during acclimatization of methanogens to distillery effluent.

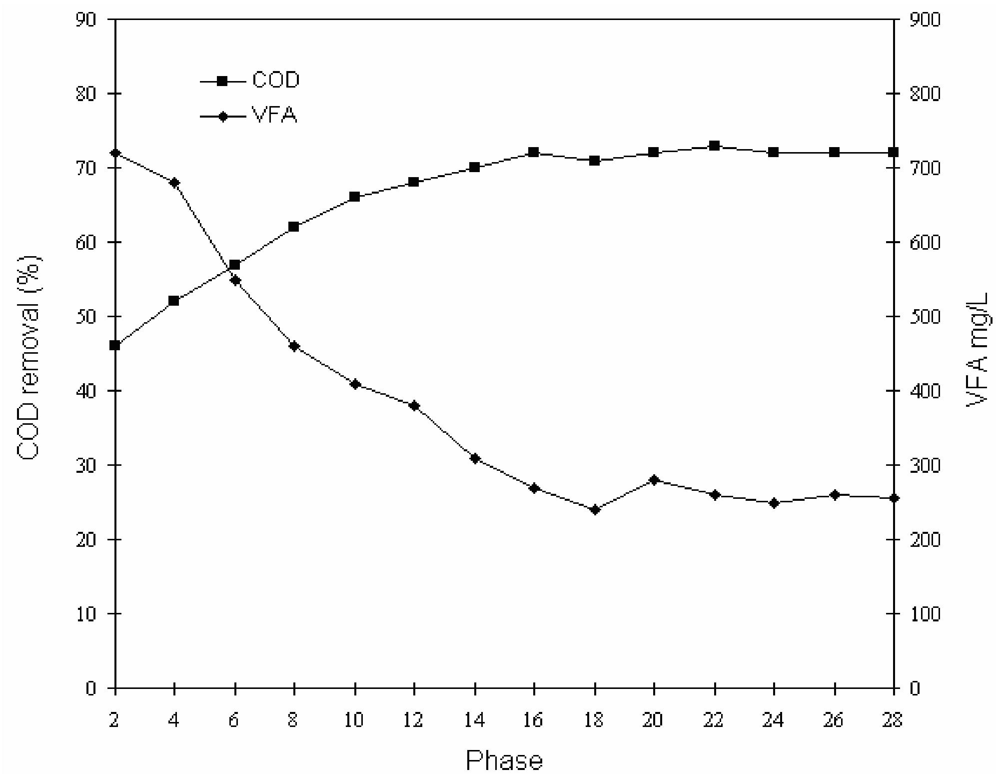

Fig. 3: COD removal and VFA in the medium during acclimatization of methanogens to distillery effluent.

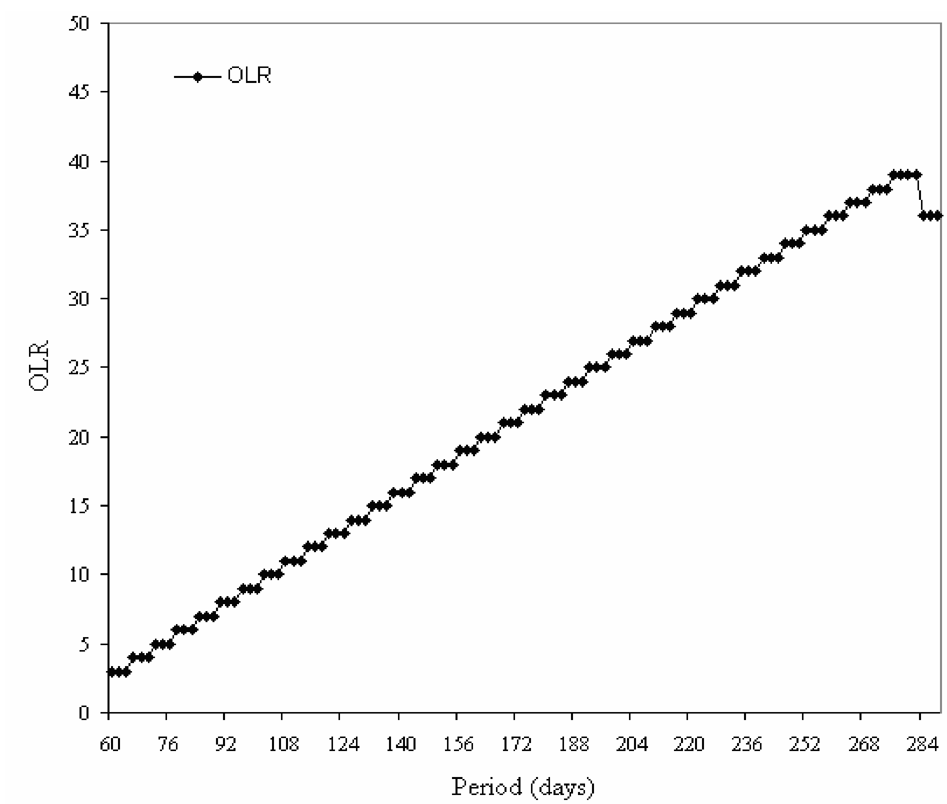

Fig. 4: Loading pattern during the treatment of distillery effluent using AMSGR.

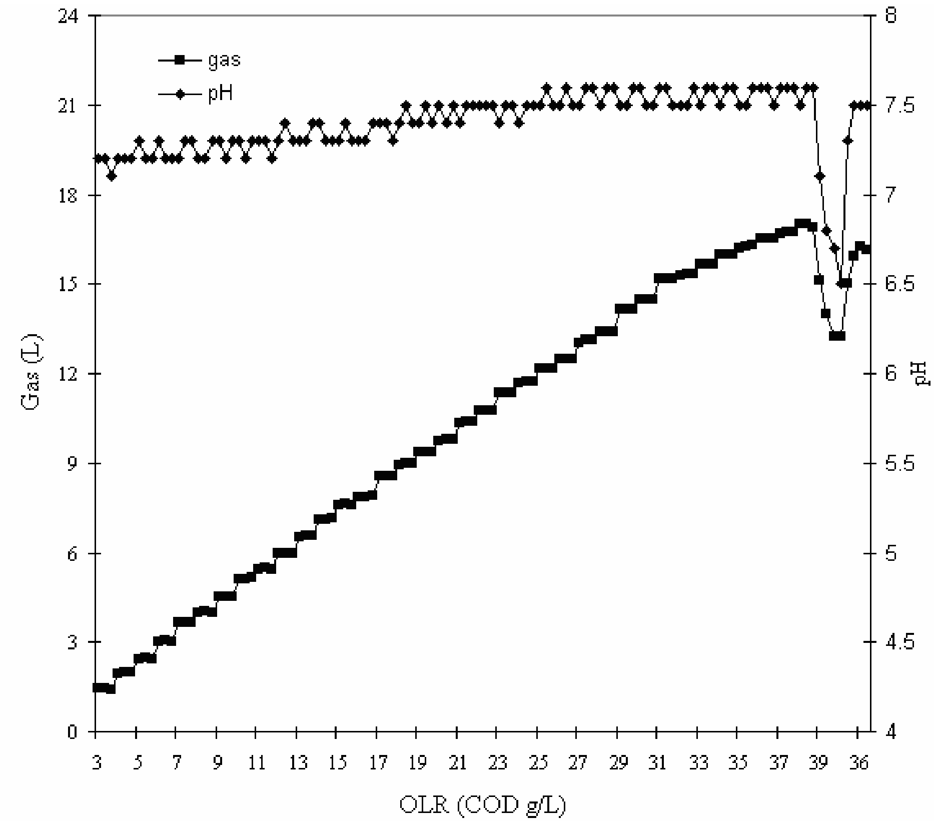

Fig. 5: Influence of OLR on biogas production and pH during the treatment of distillery effluent using AMSGR.

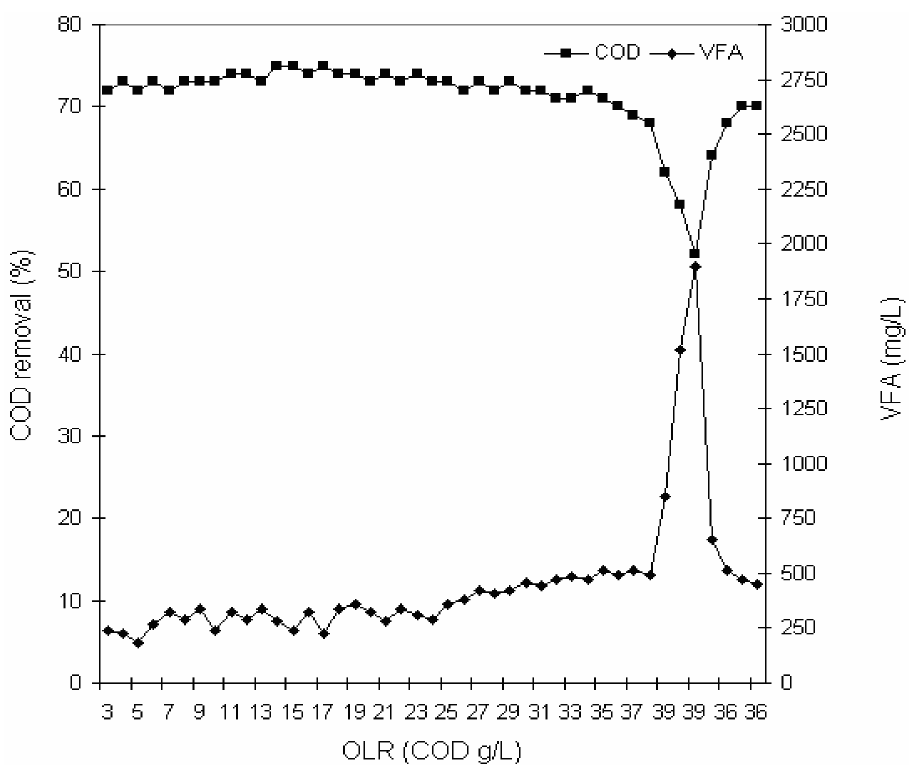

Fig. 6: Influence of OLR on COD and VFA during treatment of distillery effluent using AMSGR.

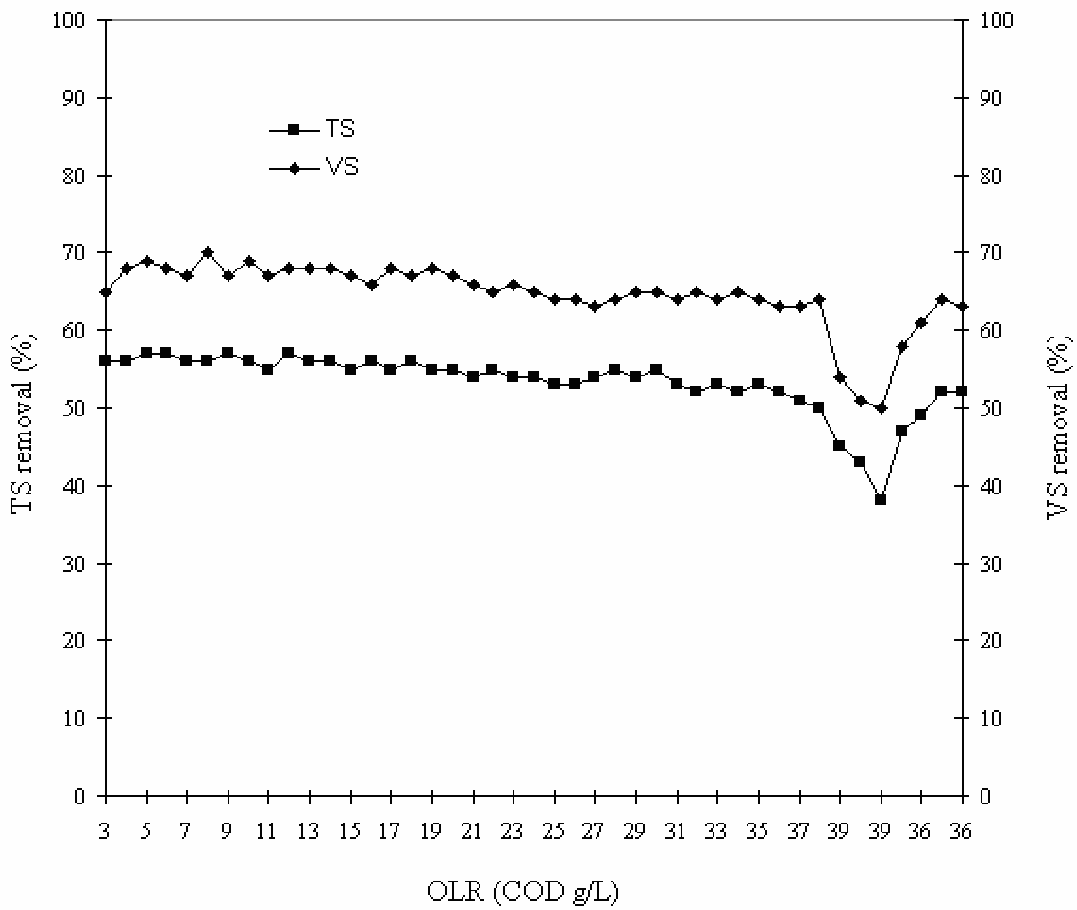

Fig. 7: Influence of OLR on TS and VS removal during the treatment of distillery effluent using AMSGR.

Mode of operation: The AMSGR was operated in a semi continuous mode. The Hydraulic Retention Time (HRT) was fixed about 2 days. Once in two days 2 L of effluent was withdrawn followed by feeding the AMSGR with 2 L of influent without disturbing its sludge bed.

Chemical analysis : The influent and effluent were analysed for Total Solids (TS), Volatile Solids (VS), Chemical Oxygen Demand (COD) and Volatile Fatty Acids (VFA) employing methods detailed in standard methods (APHA, 1998). The methane content in the biogas was analysed using a Baroda gas chromatograph equipped with a thermal conductivity detector and porapack Q column with hydrogen as carrier gas at a flow rate of 40 ml/min (Srilatha *et al*., 1995).

Results and Discussion

The distillery effluent was analysed for various physicochemical characteristics and the results are furnished in Table 2. To obtain lower organic load, the distillery effluent was appropriately diluted with distilled water and 1M NaOH was used to correct the pH to near neutral.

Acclimatization phase: The reactor was operated between 27 to 36^{0}C and started with an initial Organic Loading Rate (OLR) of 2 g/L COD at a HRT of 2 days. This OLR was maintained throughout the acclimatization phase. The pH and biogas production during this period were monitored. Fig. 2 illustrates the biogas production and pH variation during acclimatization period. The gas production increased gradually as the phase increased, reaching a maximum of 890 mL in phase 24 (each phase represented a HRT of 2 days). Beyond this phase, the biogas production was stable. The pH of the treated wastewater was in the range of 6.8 to 7.2, which is indicative of satisfactory reactor performance. The acclimatization was completed within 60 days of reactor operation.

Fig. 3 illustrates COD removal and VFA concentration in the medium during acclimatization period. The COD removal increased with time during the treatment of industrial wastewater and this is in general conformity with the findings of Chen *et al.* (1988). The COD removal was 42% in the first phase, but gradually increased with increase in phase of operation and reached 73% in phase 22. From phase 22 to phase 30, the reactor showed steady state condition with consistent COD removal of above 70%, indicating successful acclimatization of mesophilic methanogens to the distillery effluent. The VFA in

Table – 1 : Characteristics of digested cow dung slurry.

Parameter	Value
Total solids	62,654±54 mg/L
Total suspended solids	46,254± 40 mg/L
Volatile suspended solids	14,024± 21 mg/L
Colour	Dark brown

Table – 2 : Physico-chemical characteristics of distillery effluent.

Parameters	Values
pH	4-4.7
Total solids	59000-82000
Volatile solids	38000-66000
Suspended solids	750-1450
COD	101500-82000
TKN	1300-1850
Total phosphate	250-750
Sodium	110-220
Potassium	7000-7200
Calcium	2000-2500
Sulphate	1800-3000

All values except pH are in mg/L

the effluent in phase 1 was 820 mg/L; it fell down to 510 mg/L in phase 9. Higher levels of VFA in the wastewaters during the initial phases of operation indicate the prevalence of acid fermentation (Van Hanndel and Lettinga, 1994). Subsequently, the VFA in the wastewater decreased and was in the range of 510 to 240mg/L, indicating healthy anaerobic environment and satisfactory methanogenic activity.

Treatment phase : After Successful acclimatization, the treatment studies were conducted for a period of 288 days (including the acclimatization period). Fig. 4 illustrates the loading pattern during the treatment phase. The initial OLR applied during this phase was 3 gCOD/L. It was increased in a stepped manner to 39g COD/L over a period of 274 days. The increment in COD between successive OLR was about 1g COD/L.

Fig. 5 illustrates the influence of OLR on pH and gas production during treatment phase. The pH varied from 7 to 7.5 upto an OLR of 29 g COD/L. From then on it remained consistent in the range of 7.5 –7.6 up to an OLR of 38 COD g/L. The pH of the medium dropped to 6.7 when the OLR was increased to 39 g COD/L from 38 g COD/L. It is known that pH value less than 6.8 and greater than 8.3 would cause souring of the reactor during anaerobic digestion (Wheatley, 1991). To prevent the souring of the reactor during the present study, the OLR was reverted to 36 g COD/L. The reactor started exhibiting signs of recovery and the pH exhibited an increasing trend. The gas production increased as the OLR increased, reaching a maximum 16.9 L at an OLR of 38 g COD/L. Beyond this loading, the gas production decreased with increase in OLR (39 g COD/L). The impact of pH drop from 7.5 to 6.7 was reflected in the marked decrease of gas production from 16.9 L to 13.2 L when the OLR was increased to 39 g COD/L. The methane content in the biogas varied from 73 to 79%, which is comparable to 75 to 80%, reported during the treatment of spent wash in HUASB by Shivayogimath and Ramanujam, (1999).

Influence of OLR on COD removal and VFA concentration in the medium during the treatment of distillery effluent is illustrated in Fig. 6. It is evident from the figure that at an OLR of 3 g COD/L, the COD removal was 72%. As the OLR increased, the COD removal exhibited a gradual increase; at an OLR of 17 g COD/L the COD removal was 75%. Beyond this, the COD removal was stable and was in the range of 69 to 75 % upto an OLR of 38 g COD/L. The COD removal touched an all time low of 52% when the OLR was increased to 39 g COD/L.

During the stable operational phase (OLR: 3g COD/L to 38 g COD/L) of the reactor, the VFA (as acetate) levels in the medium varied from 185 to 520 mg/L. VFA started building up in the medium as the digestion proceeded and a maximum concentration of 2150 mg/L was recorded at an OLR of 39 g COD/L. VFA has been recognized as one of the important intermediates during anaerobic digestion (Ahring and Angelidaki, 1997) and is considered a central parameter for anaerobic treatment (Pind *et al.,* 1999). The impact of VFA accumulation was reflected in the marked decrease of COD removal from 69 to 52% when the OLR was increased to 39 g COD/L. Working on distillery effluent using HUASB, Shivayogimath and Ramanujam (1997) has reported a VFA concentration over 1500 mg/L at souring point. To prevent the souring of the reactor during the present study, the OLR was reverted to 36 g COD/L. The reactor then started exhibiting signs of recovery and as discussed earlier, the COD removal and gas production increased as VFA concentration in the medium decreased.

Fig. 7 depicts the influence of OLR on the removal of TS and VS from the distillery effluent during treatment phase. The determination of VS is very useful in wastewater treatment plant operation as it offers a rough approximation of the amount of organic matter present in the solid fraction of wastewater (APHA, 1998). Under stable operation conditions (up to an OLR of 38 g COD/L), the removal of TS and VS in the wastewater was in the range of 47 to 52 % and 56 to 65%, respectively. Like all other parameters the removal efficiency of both TS and VS decreased drastically when the OLR was increased from 38 to 39 g COD/L, the respective values for TS and VS being 40 and 46%.

From the foregoing it was found that the reactor performed well upto an OLR of 38 g COD/L with 48 h HRT. Further increase in loading detoriates the reactor performance and its effect was seen in reduced removal of COD, TS and VS. From the result obtained, anaerobic treatment is a viable option of treating distillery effluent with a considerable production of renewable energy methane. Further studies focusing on the microbial dynamics, impacts of environmental factors and engineering aspects would help evaluate the process and its application and pave way for pilot plant experiments. Works on these aspects are in progress.

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