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Study on the Improved Biogas Generation Through Magnetic Field Modified Anaerobic Digestion

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***Abstract*— The effect of the magnetic field (MF) on the effectiveness of biogas generation was studied and it was observed that the increased intensity of magnetic field resulted in an increase in the fermentation process. A significant increase in the methane product was recorded when the medium was exposed to the magnetic field of 0.42 T. In the magnetic field digester for the first three days (lag phase) the production of the biogas was slow which was increased in 4th to 6th days as compared to control. 4.8 Ltr. gas production was recorded in MFF as compare to 3.4 Ltr. in the control on the 6th day of the experiment. A decrease in pH was observed in 1st few days of the digestion. The value of pH remains within the range of 7 to 7.3 while in control it was fluctuated between 6.4 to 7.3. NH_3 – N was reduced to 87% which was 20% higher than the control. The total solid and volatile solid were reduced to 59% and 57% in MFF while in control they were reduced only 46% and 40% respectively. The content of suspended matter in slurry was reduced by 26.1% and the effectiveness of COD removal was increased as compare to control.**

Keywords*— *Anaerobic conditions, magnetic field, methane fermentation, biogas

I. INTRODUCTION

Today the mankind needs durable energy sources which do not affect our environment adversely the biogas appear as one of the utmost capable energy sources which is storable, transportable and it can be produced from numerous types of biomasses including animal waste particularly cow dung, human excreta and kitchen waste. The biogas plants are in use all over the country but their low efficacy restricts their required spread. In the present study a cost effective modified biogas digester is proposed, which will be fed with pretreated slurry to increase the methane yields by anaerobic digestion. New modification in digester tank includes magnetic field treatment to speedup anaerobic digestion, water conditioner and bacterial strain improvement. It has been established that exposure of aqueous salt solutions to the magnetic field (MF) causes crystallization of calcium forms into aragonite and vaterite. Aragonite and vaterite do not trigger scale deposition on walls of the fitting but in the complete volume of water, and the suspension existence formed is devoid of cementing properties [1-3].It appears, however, that procedures of magnetic treatment of fluids may be exploited in a profoundly broader scale, because with suitably selected parameters the method uses a progressive effect on various other properties of a fluid including anaerobic sludge's and wastewaters.

Alteration in properties of solutions being directly exposed to the effect of the constant magnetic field (CMF) are linked, among other things, with modification in their polarization, molecular structure and ordering of particles as well as with a change in the electric charge [4]. At the site of direct exposure to the CMF, selective ionization appears, circulating rotary currents are being formed, changes occur in electrical conductance of solutions, inner electric and magnetic fields are being generated and added magnetic moments are appearing. Molecules are ordered, polarized, and receive an appropriate charge.

Investigations done so far addressing the effect of the MF on changes in fluid properties have confirmed the option of modifying the pH value of the medium being treated. Both the distilled and tap water displayed multi extreme changes in pH value. [1, 3-5] and the phenomenon have been initiated to employ to municipal wastewaters [6, 7].

Studies additionally have verified the efficiency of applying the CMF on the biological and enzymatic activity of microorganisms responsible for processes of wastewater treatment [3]. Aarthi et al. demonstrated Flavobacterium species' pretreatment through sinusoidal MF seems to result in additional effective paper mill effluents degradation. Flavobacterium species were noticed to have four times (with respect to growth) when exposed to CMF of 100 Nt, 10 HZ for 30 h, and simultaneously, the COD, BOD, lignin, protein and phenol content in the effluent were reduced using CMF-treated cells [8].

Chaipraser et al [9] observed that the MF may advance sedimentation ability to reduce the concentration of suspensions in the effluent, activated sludge and increase the efficiency of wastewater treatment.

Very few references are available on the feasibility of applying the MF in anaerobic digestion behavior. Thus, there is a need to commence study that will avail the effect of this physical factor on the touched technological outcomes linked with reduced contaminants concentrations and with the quantity and qualitative composition of biogas produced. Properties of the MF described in literature may facilitate sedimentation of the anaerobic sludge [10, 11].

II. EXPERIMENTAL PROCEDURE

Design anaerobic biogas digester and pretreatment plant

The present study was carried out under laboratory conditions using a modified anaerobic biogas digester with magnetic field facility (MFF). Cow dung was collected from GVM, IASE Deemed University gosala, sardarshahr.

2.1 Pretreatment- Cow dung was mixed with approx. equal amount of water and mechanical size reduction was done through wet grinding machine. The thermal pretreatment with temperature 80ºC were selected to pretreat the substrate (slurry). The slurry was treated with temperatures of 80ºC for 3 hour with intermittent gentle shaking to ensure the homogeneity of temperatures. Substrate that was not exposed to these temperatures, but left under room temperature was considered as control.

2.2 Anaerobic biogas digester-Two (40 L) airtight plastic drums with following modification were used as digester.

2.2.1- Magnetic field facility (MFF)- Recycled laminated transformer core which was made out of cast iron and were assembled in 'E' shape, submersible 16 gage copper wire coiled on 'E' shape with 3.5 ohm resistance and connected with DC regulated power supply 0-32/5A. The core was fixed on plastic base and fitted on the bottom of one 500ml plastic drum. The drum that was not facilitated with magnetic field was considered as control. Both digesters were painted black.

2.3 Start-up and operation - 40L digester equipped with pH probe, stirrer, sampling ports and temperature controller (bobbin element with temperature control unit) was used in this study. The working volume of the bioreactor was maintained at 30 Liter and ran under uncontrolled pH, which was without acid or base addition. Experiments were carried out at mesophillic temperature of 42ºC to 45ºC and mixing was aided by a mechanical stirrer set at a speed of 150rpm and a semisolid liquid pump's sucking point was fixed just above the magnetic core and slurry dropping point on the top to get rid of dry slurry layer on the top ensuring proper homogeneity of magnetic field treatment.

The system was started up as batch to achieve an active acidifying culture by loading the substrate seeded with palm oil mill effluent, then sealed and purged with Nitrogen gas for 15 minutes. Semi-continuous feeding started from day 10, where a known volume of slurry was withdrawn daily from the reactor and replaced with fresh feedstock via the slurry sampling ports. In addition, approximately 50 ml of the sample was taken daily from the bioreactor through the sampling port, which then underwent series of analysis. Biogas production was measured by water displacement method.

2.4 Analytical methods

The samples taken were analyzed for volatile solids (VS), total solids (TS) and chemical oxygen demand (COD) using the Standard Method [4]. Ammonia nitrogen (NH_3-N) content was examined using the hanna HI96715 Ammonia Medium Range Portable Photometer. The composition of methane in the biogas produced was analyzed using a gas chromatography equipped with a thermal conductivity detector (TCD). The column used was a HP Molesieve 30m × 0.53mm × 0.05mm capillary column. The injector, oven and detector temperatures were set at 150ºC, 160ºC and 200°C, respectively. Argon served as the carrier gas while nitrogen was used as the makeup gas.

III. RESULT AND DISCUSSION

The magnetic field facilitates (MFF) digester and control digester performances were investigated based on the results obtained from the process monitoring for: TS reduction, VS reduction, VS/TS ratio, COD reduction, pH, NH_3-N concentration and biogas production with its methane content. Based on the analyses conducted in the experiment, it was established that the application of magnetic field on the methane fermentation processes has positive effects on the technological effects of organic compound removal as well as the production and composition of biogas.

3.1 Biogas production

The cumulative biogas production of MFF digester and control during the study period is shown in Fig-1. It was observed that biogas production was actually slow at starting in MFF, and in control both. This is presumed because biogas production rate in digester is directly proportional to specific growth of methanogenic bacteria [14]. During the first 3 days of observation, there was less biogas production which was mainly due to the lag phase of microbial growth. Whereas, in the range of 4 to 6 days of observation; biogas production increases substantially due to exponential growth of methanogens.

Highest biogas production rate of 4.8 L in MFF and 3.4 in control was measured on day 6. On the commencement of control digester, biogas production was observed to decrease considerably and, this is probably due to unregulated pH, which concurrently leads to increase in concentration of ammonia nitrogen that might be assumed to inhibit the process. It was reported by Chen Ye, et al [15] that high concentration of ammonia nitrogen is toxic to anaerobes, which decreases the efficiency of the digestion and upsets the process. Besides, the fluctuations in the daily biogas production found during the MFF and control digesters, it could also be attributed to the varying input of VS load.

Yavuz and Celebi [7] while working on the effect of MF on the activity of activated sludge in the process of wastewater treatment observed that at varying pH values (6.0 to 8.5) of wastewaters and at varying induction of the MF (in the range of 8.9-46.6 mT). The effectiveness of the treatment process was higher by 44% than in the control variant. The maximum activity of microorganisms was noted at magnetic induction of 17.8 mT, whereas along with an increasing MF induction value it was observed to reduce. The authors demonstrated that the MF exerted a positive effect on the metabolic activity of microorganisms, which contributed to enhanced effectiveness and, therefore, to the improved effects of the wastewater treatment process. This also was the case in the present experiment. The physical factor was observed to elicit a positive effect on the activity of activated sludge microorganisms, which has been corroborated by the achieved effects of the treatment process in respect to control.

In the experiment with the application of MFF, the maximum methane content in biogas production was noted 73.4% whereas in the control digester accounted 57.84%as shown in Fig -2. It also has been proved that strong magnetic fields with appropriately selected parameters affected changes in such properties of a fluid as: surface tension, density, viscosity, light extinction, and wettability of solid bodies [3, 5]. This may appear significant from the viewpoint of both more effective sedimentation of the sludge in reactors as well as removal of gaseous metabolites of anaerobes.

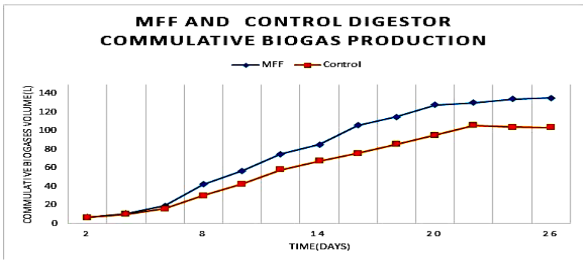

Fig. 1

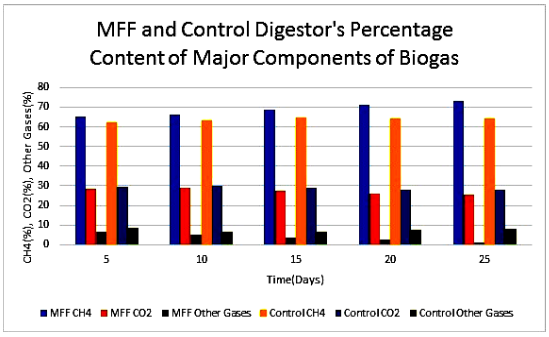

Fig. 2

3.2 pH Alkalinity

The available work on anaerobic digestion of organic waste has disclosed that pH of substrates has significant impact on the rate of production and yield of biogas by the substrate. Methanogenic bacteria are pH sensitive in nature. The substrates pH was measured on every second day of digestion in accordance to Chaiprasert et al. (2006)[9], pH reading is an indicator of system process stability of anaerobic process. A decrease in the process pH was observed in the first few days of the digestion and this is due to high volatile fatty acid (VFA) formation in both digester control and MFF. The values of the pH in MFF digester, determined in the present work falls within the range of 7 to 7.3, which is optimum pH for anaerobic digestion, on the other hand control digester showed many fluctuation as shown in figure 3. At the end of this experiment, in MFF digester NH_3-N was reduced to 87% which is 20% higher than that at mixing ratio 1:5 and 1.5:5. Ji et al[12].

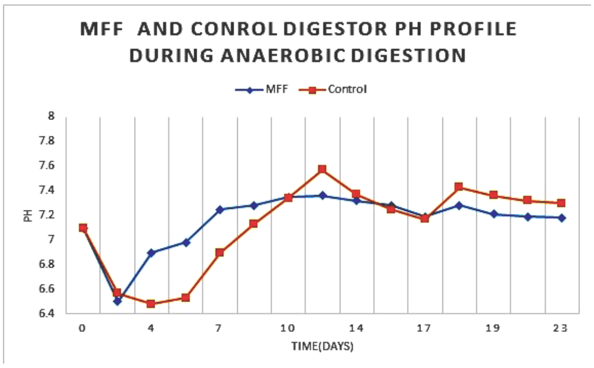

Fig. 3

3.3 Total solids and volatile solids in bioreactor

In the evaluation of anaerobic digestion performance, TS and VS destruction is a vital parameter [Fig- 4 and 5]. The utmost operative performance in terms of VS degradation was witnessed during MFF digestion, possibly through efficient hydrolysis in the acid phase. However, on day 10^{th}, when the control digester was operating under semi-continuous manner, removal of VS was observed with large fluctuations.While in control digester there was still tendency for further TS and VS reduction with little or non-biogas production, seemingly because of the inherent barely biodegradable constituents, accordingly higher ammonia concentration contributes to process inhibition. According to Nielsen and Angelidaki [16], cow's manure used in this study has lignocellulosic rich resources; hence making anaerobic digestion was more non-optimum in case of control Digester compared to MFF digester. The TS and VS reduction of (59% and 57% in MFF) (46% and 40% in control), respectively was stably accomplished during the operation. Additionally, physical interference caused by buildup of inorganic matter inside the bioreactor, can be determined by the VS/TSration.VS/TS ration during the entire operation averaged 0.2 in MFF and 0.6 in control with little variation. This implies that no accumulation of grit occurred and the bacteria populations are in more favorable condition in MFF digester compare to control digester. It was concluded by Chae*et al.*, [17] that the digester's VS/TS ratio is an exceptional indicator to determine the accumulation of unsolicited materials and the capability of mixing system employed. Thus, these results signify that the MFF digester is more under adequate mixing than control digester.

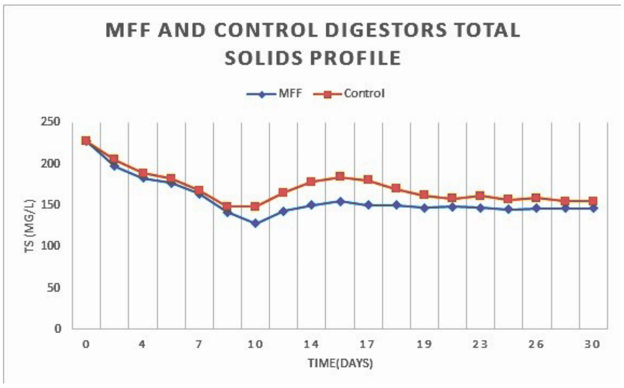

Fig. 4

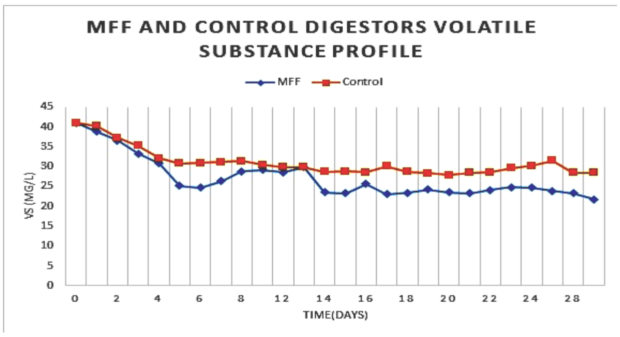

Fig. 5

3.4 COD reduction in bioreactor

From Fig 6 it can be seen that the average COD removal efficiency of the control digester was comparatively lower than the MFF. This result was believed to be due to the high COD exhibited by the inoculum which leads to increase in influent COD concentration. In effect, it dominates the microbial activity thereby resulting in lower COD removal efficiency of control digester. The content of organic compounds in the supernatant was determined as the content of COD. In respect of the control series where COD content reached 632 mg/L, the lowest concentration of organic compounds was reported in MFF digester 559 mg/L. In this case, the effectiveness of organic compounds removal increased in the last 10 days by 14%. Tomska and Wolny (18) demonstrated that the MF with 40 mT induction did not contribute to improved reduction of COD from crude wastewaters and had a positive result only on the nitrogen compounds. The magnetizer was placed on a pipe used for recirculation of activated sludge. The crude wastewaters treated were domestic sewage. No substantial differences were renowned in the effectiveness of organic contaminant biodegradation between the system with MF and the control one [18].

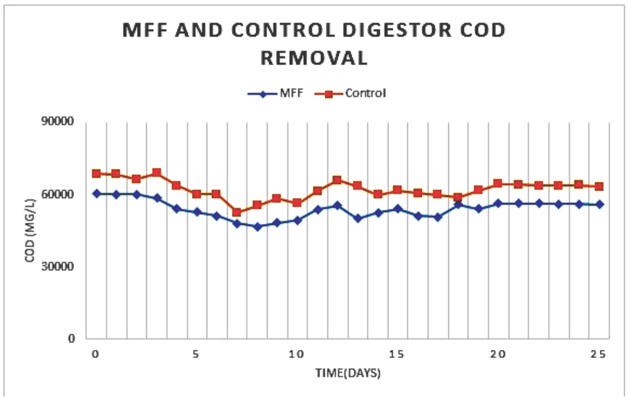

Fig. 6

IV. CONCLUSIONS

Under experimental conditions applied, the MFF was shown to exert a significant effect on the process of methane fermentation. An increase was observed in the value of methane content in biogas production. The magnetic field of 0.42 [T] caused significant changes in the analyzed parameters of the methane fermentation process. The analysis of biogas composition demonstrated that there were significant differences between control and MFF digester production. A positive effect of the MF was established in respect to the sedimentation process of anaerobic slurry and reduction of COD concentration in the effluent. At the 0.42 T MF the effectiveness of COD removal increased by $\pm$14.0% compared to the control without the physical factor.

Thus, it is necessary to further study the effects of magnetic field on biogas anaerobic digestion using different approach such as substrate pretreatment and development of mix inoculum of methanogenic bacteria in reference to time reduction in methane generation as well.

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