Biogas Generation using Anaerobic Digestion of Pulp And Paper Sludge

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Abstract- *Currently the economic benefits of the pulp and paper industries have become one of the most important industrial segments in the world; however, the treatment of effluents is still a challenge and an environmental barrier. The effluent from pulp and paper mills can contain a high amount of organic matter.Also the produced primary and activated sludge can be used for biogas production and to reduce the sludge amount at the same time. The objective of this study is to Characterize the pulp and paper sludge from a board production industry, Set up anaerobic digester for treating pulp and paper sludge, Determine the biogas generation potential of pulp and paper sludge for various solids concentration ratio and assess the amount of BOD, COD, TS and VS of digested sludge.*

Keywords- Biogas, Pulp and paper sludge, Anaerobic digestion.

I. INTRODUCTION

Scarcity of petroleum and coal threatens the supply of fuel throughout the world also problem of their combustion leads to research in different corners to get access the new sources of energy, like renewable energy resources. Some of the renewable energy resources are solar energy, wind energy, different thermal and hydro sources of energy and biogas. But, biogas is distinct from other renewable energies because biogas utilise the organic wastes and at the same time producing fertilizer and water for use in agricultural irrigation. Developing countries like India a very big problem they are facing is deforestation, for fuel supply most of the parts in India depends on charcoal and fuel wood which requires cutting of forest. Due to deforestation the fertility of land decreases by soil erosion. Use of dung, firewood as energy is also harmful for the health because they cause air pollution. Biogas does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply.

For production of biogas in an effort to meet the rising demand for environmentally friendly fuels, many organic residues, for example sludge from wastewater treatment in pulp and paper mills; have been tested with respect to their prospective use as substrates. Being a fossil free fuel, biogas is used in combustion engines, is increasing in popularity, and the necessary infrastructure for biogas is currently being developed in parts of Sweden where biogas was not previously available (Paulsson, 2011). There are several benefits like making low grade boards, etc in using sludge from pulp and paper mill in large scale biogas plants. Paper sludge consists of high content of organic substances although this is not exploited efficiently for biofuel production. Moreover, from point sources large quantities of sludge are produced and thus it is not necessary to aggregate material to achieve viable quantities for anaerobic digestion. Some of the economic advantages to mills from On-site anaerobic digestion are low costs of transport, the potential to coordinate maintenance and operation with the existing organisation, an abundant supply of low-temperature excess-heat and revenues from biogas production. The digestate which is biologically treated could be sold as a soil amendment. Hence, the objective of this research was to produce biogas from paper waste blended with cow dung.Main objective of the present study is to treat pulp and paper sludge by digestion in an anaerobic reactor for generation of biogas. The Specific objectives are tocharacterizethe pulp and paper sludge from a board production industry, toset up anaerobic digester for treating pulp and paper sludge, to determine the biogas generation potential of pulp and paper sludge for various solids concentration ratio, to assess the amount of BOD, COD, TS and VS of digested sludge.

II. MATERIALS AND METHODS

Study area

An insulation board industry which is nearby Mysuru, that manufactures transformer insulating board using paper as a raw material for the production process generating large amount of paper sludge in an effluent treatment plant is considered for the study. The bench scale study was carried out to degrade pulp and paper sludge in an anaerobic digester using cow dung as a seeding material for biogas production. A total feed of 1kg is maintained throughout this study.

Sampling and Characterization

Samples were collected in a polythene bag and ice is used for sample storage and transportation and it is placed in sample coolers. Samples were drawn six times from the effluent treatment plant to feed the anaerobic digester. The sample was prepared by crushing the paper sludge and then mixed with water and seeding material cowdung is added along with water and paper sludge. Table 1.1 shows the initial characterization of paper sludge.

III. EXPERIMENTAL SETUP AND METHODOLOGY

Details of reactor

A 5L borosilicate bottle is used as an anaerobic digester. Graduated 1L capacity gas collector was fabricated with borosilicate glass with 2L aspirator bottle. The gas collector was filled with coloured water (NaoH + methyl orange indicator). The gas generated in the digester displaces the coloured water from the gas collector to the aspirator bottle. A soft rubber tube is used for the flow of gas.

Proportioning and Feeding

The various proportional ratios of Paper Sludge (PS) and Cowdung (CD) is fed into reactor i.e., 80:20(PS: CD), 70:30, 60:40 (i.e., 600g of partially degraded paper waste and 400g of cow dung was added into the batch anaerobic digester) and 100:0. A total feed of 1kg is maintained throughout the study.

Operation and maintenance of anaerobic digester for pulp and paper sludge.

Experiments were conducted in 5L capacity borosilicate bottle. The working volume of the digester is 3L. These were wrapped in black plastic tapes to avoid algal growth. The digesters were initially charged with 80:20 ratios, i.e., 800g of partially degraded paper waste and 200g of cow dung was added into the batch anaerobic digester. Water was added to it in the ratio of 1:2 and mixed homogeneously and then fed to an anaerobic batch digester. The slurry sample was allowed for digestion and at every 24 hours interval, the volume of gas generated was noted by displacement of the coloured water (using methyl orange indicator) in the graduated gas collector column for 7 days. The various ratios of Paper waste: Cowdung is fed into reactor i.e., 80:20, 70:30, 60:40 and 100:0. The effects of various ratios of biogas yield were studied. All the experiments were carried out in a mesophilic temperature (Range 27 0 C to 30 0 C).

Gas composition analysis

Gas composition was analysed by liquid displacement method i.e., 1000mL of sodium hydroxide (NaoH) solution is taken in a beaker and the gas column is kept inside the sodium hydroxide solution beaker and kept it for two or three days to check the composition. The sodium hydroxide solution will rise in the gas column till the carbon-dioxide is present. The remaining portion of the column is methane and other traces of gas like hydrogen sulphide etc.

Table 1.1 Initial characterization of paper sludge

Parameters	Value
pH	6.9
BOD	104.96mgL
COD	262.4mg/L
Nitrate	143.33mgL
Phosphate	70.15mg/L
Total solids	196mg/L

BOD and COD values are initially high this is due to the presence of partially degraded paper sludge. The percentage reduction of COD and BOD are 28% and 22% respectively as shown in Figure 1.1.

The percentage reduction of TS and VS are 23% and 30% respectively as shown in Figure 1.2. The carbonaceous organic matters in the digester are utilized by the bacteria which help in the reduction of TS and VS. The percentage reduction of TS and VS are comparable with the study conducted by (Lin Yunqin et al., 2010) where percentage reduction is 20-25% and 28-36% respectively.

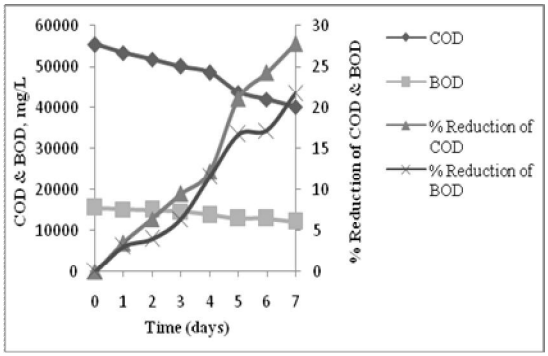

Figure 1.1 Variation of COD & BOD with time for 80:20 ratio of PS: CD

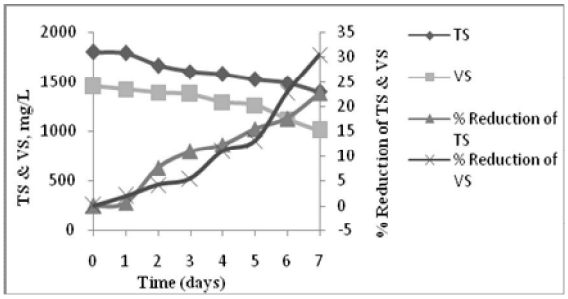

Figure 1.2 Variation of TS and VS with time for 80:20 ratio of PS: CD

From Figure 1.3 it can be observed that the values of COD and BOD are initially high, this is due to the decreases in partially degraded waste and increase in paper sludge content used in 70:30 ratio. As the retention period increases there a gradual decrease in COD and BOD values. The COD reduction has a direct effect on the yield of gas generation i.e. as the COD reduces, the gas production increases, the percentage reduction of COD and BOD was 18% and 20% respectively, COD reduction is due to the conversion of biomass to carbon-dioxide and methane.

From the Figure 1.4 it is observed that TS decreases along with VS as the retention time increase. The carbonaceous organic matters in the digester are utilised by the bacteria which help in the reduction of TS and VS. The initial TS were 1785mg/L which was reduced to 1487mg/L at the end of the study period. The VS reduced from 1438mg/L to 994mg/L the percentage reduction of TS and VS was 17% and 31%, the reduction in VS is comparable with results of (Bayr and Rintala2012)achieved a removal of 25–40%, the VS is an important parameter the optimum VS/TS ratio should be above 0.5 which is favourable for microorganisms to carry out their activity effectively (Metcalf and Eddy, 2003). The VS/TS ratio was 0.62 to 0.69 throughout the study period. Increase of TS in anaerobic process increases the biogas production (Eze et al., 2012).

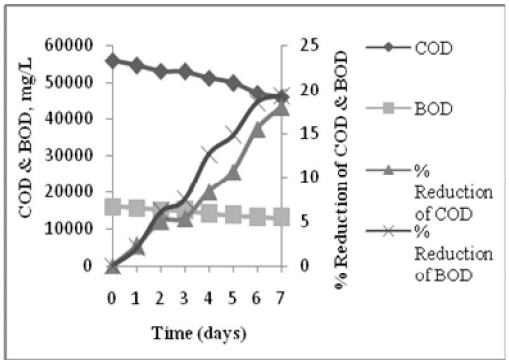

Figure 1.3 Variation of COD & BOD with time for 70:30 ratio of PS: CD

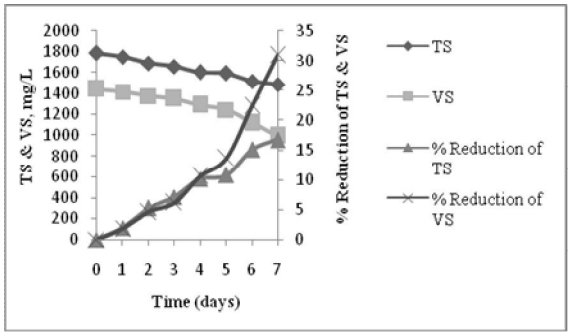

Figure 1.4 Variation of TS and VS with time for 70:30 ratio of PS: CD

From the Figure 1.5 shows the plot of COD and BOD with time. It was observed that there is a sudden fall in the COD value at the fourth day of digester loading and the gas yielded high for the particular day. This show gradual decrease in COD increases the yield of gas. The percentage reduction of COD was 18% for which the BOD was 19%. Less reduction in COD is due to the fibre content of paper sludge.

From the Figure 1.6 it is observed that TS decreases along with VS as the retention time increase. Compared to previous ratios like 80:20 and 70:30 the TS and VS are comparatively less. This may be due to the less percentage of paper sludge in the digester. The TS was reduced from 1762mg/L to 1421mg/L at the end of the study period. The VS was reduced from 1412mg/L to 952mg/L the total reduction TS and VS was 19% and 33% respectively. The results contain for TS and VS are nearby comparable with the results of (Ofoefule et al., 2009) where percentage reduction is 15-21% and 28-37% respectively.

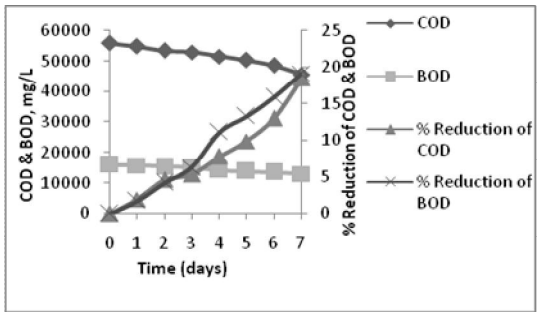

Figure 1.5 Variation of COD & BOD with time for 60:40 ratio of PS: CD

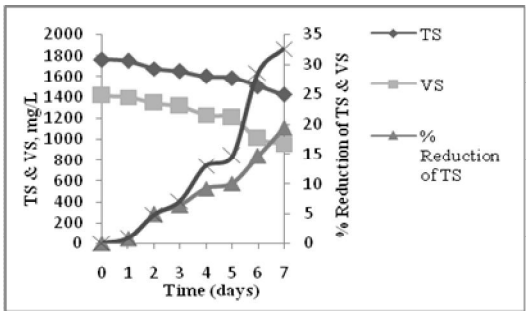

Figure 1.6 Variation of TS and VS with time for 60:40 ratio of PS: CD

From the Figure 1.7 shows that the COD and BOD with time. Even though paper sludge contributes some BOD there is initially less BOD because as there is no presence of cowdung. The percentage reduction of COD and BOD was 40% and 56% respectively. The reduction of COD depends on the nature of pulp and paper sludge. The obtained results of COD are comparable with the study conducted by Banu R. et al., (2007) and Satoto et al., (2010) where percentage reduction is 36-42%.

From the Figure 1.8 it is observed that TS decreases rapidly than VS, as the retention time increases. Compared to previous studies like 90:10, 80:20, 70:30 and 60:40 ratios the TS and VS value is comparatively less. This is because we have used only paper sludge as a feed stock to feed the digester with the absence of cowdung. The TS was reduced from 1358 mg/L to 889 mg/L at the end of the study period. The VS was reduced from 756 mg/L to 397 mg/L. The percentage decrease in VS is 48% which is comparable with the results of (Jaakko Puhakka 1992) where percentage decrease in VS is between 40-50%.

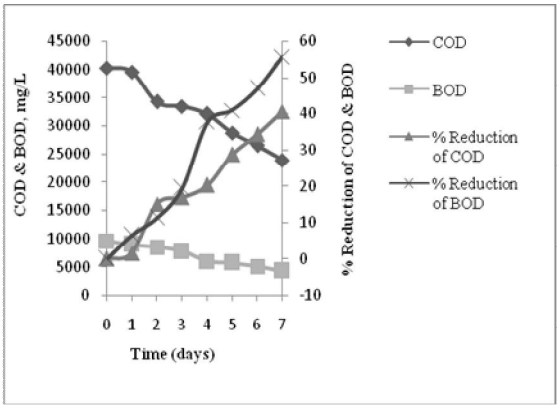

Figure 1.7 Variation of COD & BOD with time for 100:00 ratio of PS: CD

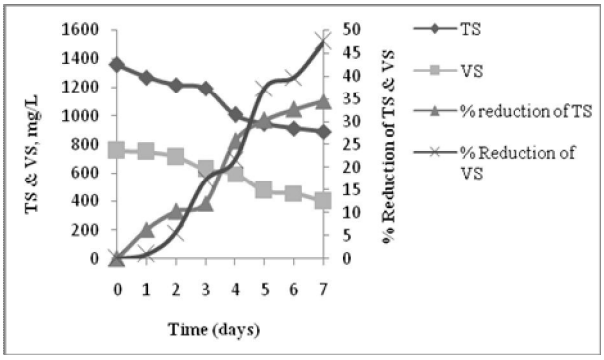

Figure 1.8 Variation of TS and VS with time for 100:00 ratio of PS: CD

IV. BIOGAS GENERATION

Among the five proportions of waste loaded into the digester, the 70:30 ratio of PS: CD has yielded maximum amount of biogas and it shows that the paper sludge and cowdung has good potential for generation of biogas. The daily variation in gas generation and temperature was recorded for different ratios of waste slurry. The ratios mix proportions of paper sludge and cowdung for study were 80:20, 70:30, 60:40 and 100:0 for which the cumulative gas generated collected 840 mL, 895 mL, 875 mL and 430 mL respectively. Thus 895 mL of cumulative gas generated is considered as an optimized gas generation. The least gas generated was observed in 100:0 ratio of PS: CD that is about 430 mL. In all the ratios considered it took 2 to 3 days for stabilization and the generation of gas was observed from 3rd or 4th day of loading. After the fourth day of digester loading there is a gradual decrease in daily yield and the gas production was less towards the end, which shows the decline phase of anaerobic bacteria. After the peak value of gas production there is a fall in daily gas generation, this is due to the fact that microorganisms responsible for biogas production have consumed a large amount of the substrate and hence drops its activity (IIaboya et al., 2010). The method adopted here to measure the amount of biogas does not give the appropriate measurement of biogas generated because biogas gets collected in the graduated collector only when the digester gets filled completely.

Figure 1.9 shows that compared to other ratio 70:30 ratio of PS: CD has yielded more biogas generation than 80:20, 60:40 and 100:0 of PS: CD i.e. around 895mL of total gas is collected from the reactor. But optimal value in methane generation is obtained in 60:40 ratios of paper sludge and cowdung i.e. about 775mL hence this condition is called as optimal condition. Table 1.2 shows the Composition of Biogas for various ratio of PS: CD.

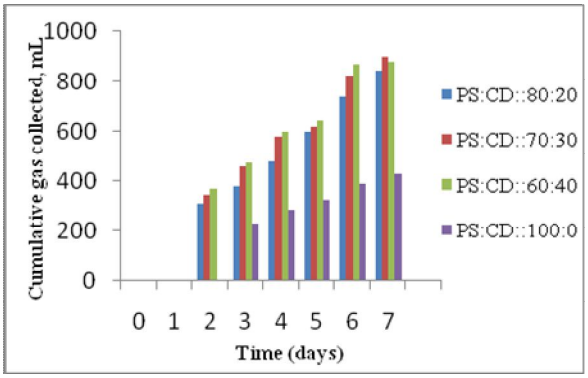

Figure 1.9 Daily variation of biogas for different ratio of PS: CD

Table 1.2Composition of Biogas for various ratio of PS: CD

Sl. No.	PS:CD Ratio	Total gas collected in mL	Methane in mL	Carbon-dioxide in mL
1	90:10	760	600	160
2	80:20	840	700	140
3	70:30	895	750	145
4	60:40	875	775	100
5	100:0	430	250	180

V. CONCLUSIONS

Based on the investigation, observations made and results obtained from the paper sludge and cowdung, the following conclusions are drawn from this research paper.

- BOD and COD content were high in the combination of paper sludge and cowdung. This is due to the presence of paper sludge content in the slurry.
- Total solids and Volatile solids concentration is reduced in various ratios of paper sludge and cowdung this is due to the utilisation of solid content in the slurry by microorganisms.
- In all mix proportions considered, it took 3 to 4 days for stabilization and the generation of gas was observed from the 3rd or 4th day of loading.
- Optimal value in methane generation is obtained in 60:40 ratios of paper sludge and cowdung i.e. about 775mL.
- The gas production is very less in 100:0 ratio of PS: CD this is due to the fibre content which is present in the paper sludge.
- Batch experiment studies using paper sludge and cowdung in different ratio can be a suitable source for biogas production

VI. SCOPE FOR FUTURE STUDY

- The experiments can be carried out in the semi-continuous anaerobic digester.
- Tailor made bacteria can be used instead of cowdung as a seeding material to see the efficiency in the production of biogas.
- Provision for stirrer in the digester can be made, which avoids the scum formation in the digester.
- Asbestos sheets may be used to cover the digester to increase the temperature which in turn increases the yield of biogas.

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