Annals of Biology **40** (1) : 30-33, 2024

Impact Score : 0.32 (Scopus)

Biogas Potential of RCF Based Kraft Paper Mill Effluent by Anaerobic Digestion

ABHISHEK TYAGI*, MOHD. SALIM[1], PRATIBHA NAITHANI AND M. K. GUPTA[1]

Department of Environmental Science, Graphic Era (Deemed to be University), Dehradun-248 002 (Uttarakhand), India

**(e-mail: abhishektyagi34@gmail.com; Mobile: 90454 48389)*

(Received: July 15, 2023; Accepted: September 4, 2023)

ABSTRACT

Anaerobic treatment is an alternative and effective method for treatment of effluent generated from the paper mills. The generation of biogas, a renewable energy resource as a byproduct of the anaerobic treatment, is the major attraction to this treatment method. A laboratory prototype of UASB reactor was fabricated to treat the effluent collected from RCF based kraft paper mill to evaluate the production of biogas. The experiments were carried out at mesophilic temperature range (35-39°C) at variable organic loading rate (OLR). The hydraulic retention time (HRT) was maintained around 11 h during all the experiments. One-way ANOVA was used to determine the significance of results for biogas production at different OLR. The experimental finding indicated that the RCF based kraft paper mill effluent had a good potential for treatment through the process of bio-methanation, which when incorporated as pre-treatment step, improved the overall performance of Effluent Treatment Plant (ETP) along with added advantage of biogas generation. The optimum OLR at which maximum COD reduction of around 72% and along with biogas generation of 0.56 m^3/kg COD reduction was achieved around 9.14 kg COD/m^3 day.

Key words: Anaerobic digestion, biogas, effective OLR, kraft paper mill effluent, metahne

INTRODUCTION

Scientific management of the waste by transforming it into energy-related products through anaerobic digestion provides a viable solution to the waste management issue in a constructive manner (Fermoso *et al.*, 2018). So far, various types of treatments (primary, secondary and tertiary) have been developed and applied in order to enhance the treatment efficiency and to reduce the amount of the produced final wastes and also to prevent the toxic effects induced by the presence of hazardous compounds when released into the receiving environment (Kamali *et al.*, 2016). Anaerobic digestion is considered as a stable process for wastewater treatment (Bakraoui *et al.*, 2019a). Useless material produced from various industries such as fruits, food, pulp and paper can be used for the production of biogas (Bhatia *et al.*, 2020). Anaerobic digestion has attracted attention in recent years due to its inherent merits such as biogas production and minimizing the solid waste production, which has made it an attractive method for the treatment of pulp and paper mill wastewater (Reungsang *et al.*, 2016). In fact, it provides a significant reduction in the input material mass (Bakraoui *et al.*, 2019b). Moreover, the huge quantity of organic waste matter produced from recycled paper industry may be converted to biomethane and valorized to a renewable energy (Bakraoui *et al.*, 2020). This technique is more effective than any other treatment techniques in terms of low energy requirement and design simplicity (Ekstrand *et al.*, 2020). The UASB digester is most commonly used for industrial and municipal wastewater treatment, which is operationally stable and energetically efficient (Chen *et al.*, 2017). The UASB process is a combination of physical and biological processes. The main feature of physical process is separation of solids and gases from the liquid and that of biological process is degradation of decomposable organic matter under anaerobic conditions (Sangeetha and Sharmila, 2020). These experiments were conducted to evaluate the efficacy and feasibility of lab scale up-flow anaerobic digester (UAD) in biogas production at different organic loading

[1]Environment Management Division, Central Pulp and Paper Research Institute, Saharanpur-247 001 (Uttar Pradesh), India.

rate (OLR) from effluent collected from RCF based kraft paper mill by anaerobic digestion.

MATERIALS AND METHODS

In the present work, a RCF based paper manufacturing mill located at Muzzafarnagar, Uttar Pradesh, India was selected for effluent collection. Grab samples of effluent were collected from the sedicell outlet of the effluent treatment plant and stored by refrigerating at 4°C and then brought to room temperature prior to analysis.

A laboratory scale up-flow anaerobic digester (UAD) was installed at Environmental Management Division, CPPRI, Saharanpur. The UAD was fabricated using plexi glass with an internal diameter of 9.92 cm, radius 4.96 cm and overall height of 161.43 cm. Total volume of the reactor was approximately 12.47 litre. A gas headspace equivalent to 1 liter (about 155.43 cm height) was maintained above the effluent line. A screen was placed to arrest the floating material at a height of 147.43 cm. A peristaltic pump was used to feed the wastewater (influent) with a flow rate of 0.62 l/h into the reactor. The connecting pipeline of effluent was sealed to prevent gas leakage. The gas outlet was connected to a water displacement system to measure the gas production. The UAD was inoculated with granular anaerobic sludge collected from a full-scale UASB digester. During the startup, the washed sludge in the digester was continuously fed with kraft paper mill effluent with a low flow rate using peristaltic pump to get the anaerobic microbes acclimatized to new substrate (RCF based kraft paper mill effluent), for around 12 days. This step was undertaken to adapt the anaerobic sludge to the new temperature (37±2°C) conditions and to avoid their deterioration. The schematic diagram of the UAD installed is shown in Fig. 1.

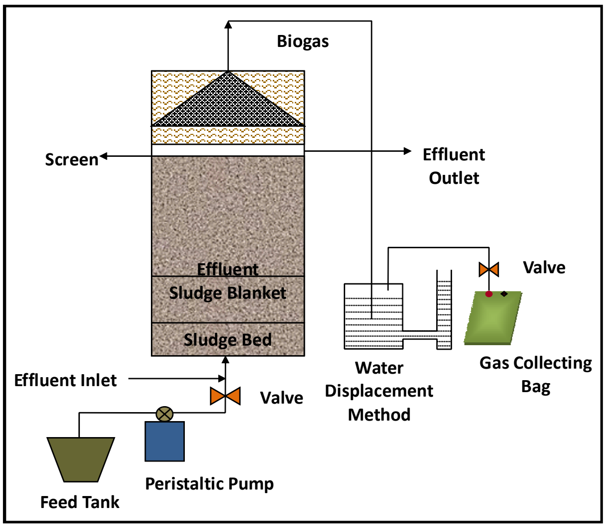

Fig. 1. Schematic diagram of lab scale up-flow anaerobic digester (UAD).

The experiments were determined at diluted concentration of COD ranging between 5000 to 15500 mg/l. The hydraulic retention time (HRT) for all the experiments was 20.11 h. The organic loading rates (OLR) were maintained at a range of 6.10, 9.14, 12.19 and 15.24 gCOD/l×day. The experiments were carried out at mesophilic temperature range i.e. 35-39°C. The samples were analyzed for the pH, alkalinity, TDS, TSS, TS, BOD, COD, VFA, inorganic and organic solids in triplicates. All the analysis was performed as per the methods provided in Table 1.

RESULTS AND DISCUSSION

The effluent from sedicell outlet of RCF based kraft paper mill located at Muzaffarnagar, Uttar Pradesh, producing kraft or brown paper grades was collected for evaluating the efficiency of UAD for effluent treatment and biogas production. The characteristics of the waste water effluent from the sedicell outlet are shown in Table 2.

Table 1. Analytical methods used for evaluation of water samples

Parameters	Method used
pH	IS: 3025; P- 11 (Potentiometer)
Chemical oxygen demand (COD)	IS: 3025; P- 58 (Open reflux method)
Biochemical oxygen demand (BOD)	IS: 3025; P- 44 (Three days incubation at 27°C)
Total dissolved solids (TDS)	IS: 3025; P- 16 (Gravimetric method)
Total suspended solids (TSS)	IS: 3025; P- 17 (Gravimetric method)
Alkalinity	IS: 3025; P- 23 (Indicator method)
VFA	TM III - B18, 2001, CPPRI (Reflux and titration method)
Inorganic solids	IS: 3025; P- 18 (Gravimetric method)
Organic solids	IS: 3025; P- 18 (Gravimetric method)

Table 2. Physico-chemical analysis of feed influent to UAD

S. No.	Parameters	Results
1.	pH	6.89±0.24
2.	TS (mg/l)	22,753±146.10
3.	TSS (mg/l)	3,171±21.26
4.	TDS (mg/l)	19,389±112.10
5.	COD (mg/l)	15,500±132.82
6.	BOD (mg/l)	10,749±102.02
7.	VFA (meq/l)	32.14±5.12
8.	Alkalinity (meq/l)	1.8±0.52
9.	Inorganic solids (%)	52.14±4.29
10.	Organic solids (%)	47.86±6.32

The current UAD was maintained at different organic loading rates (OLR) of 6.10, 9.14, 12.19 and 15.24 gCOD/l×day. The COD reduction and biogas generation were determined on regular basis to evaluate the removal of organic pollutants from the feed water. The biogas production increased significantly with increase in the OLR (Table 3). The maximum biogas production was observed at effective OLR i.e. 9.14 gCOD/l/day. Beyond 9.14 gCOD/l/day, increase in OLR showed decrease in COD reduction efficiency along with reduced biogas production. Similar results were observed in a study conducted by Sangeetha and Sharmila (2020), where maximum COD removal of 88% and a methane yield of 0.32 m^3/kg were achieved at OLR of 8 kg COD/m^3/day.

At effective OLR 9.14 gCOD/l/day, the COD reduction was maximum i.e. 72.43% along with maximum biogas production of 7.7 liters as compared to other OLR (Fig. 2). One-way ANOVA was used to determine the significance of results for biogas production at different OLR. The results indicated that the null hypothesis for equality of different treatment means got rejected because calculated value (F_{cal}) of F-statistic (10.65) was greater than its critical value (F_{crit}) i.e. 3.49; $F_{cal}>F_{Crit}$, which fell in rejection region at 95% confidence level. Further p-value (0.001) which was less than 0.05 indicated the same (Tables 4 and 5). Thus, OLR significantly affected the biogas production.

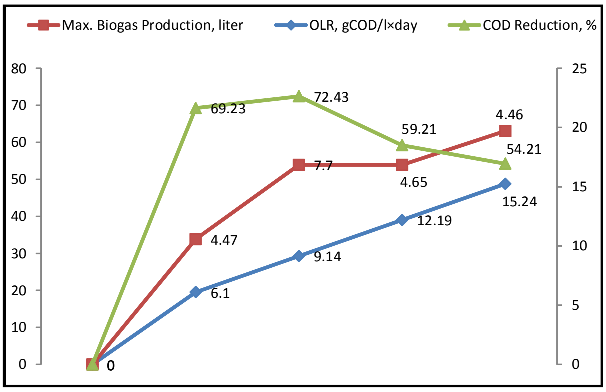

Fig. 2. Biogas production along with COD reduction at different OLR.

Table 4. ANOVA single factor summaries

Groups	Count	Sum	Average	Variance
A (6.10 OLR)	4	1.65	0.4125	0.011625
B (9.14 OLR)	4	1.88	0.47	0.005
C (12.19 OLR)	4	1.02	0.255	0.003767
D (15.4 OLR)	4	0.88	0.22	0.001533

The effective OLR, at which COD removal was significant, was 9.14 gCOD/l/day. The maximum COD reduction at effective OLR was determined as 72.43% with biogas yield of 0.56 m^3/kg COD reduced (at normal temperature and pressure).

CONCLUSION

The experimental results and statistical analysis indicated that RCF based kraft paper mill effluent had a good biodegradability

Table 3. Maximum biogas production and COD reduction at different OLR

S. No.	OLR (gCOD/liter × day)	Max. COD reduction (%)	Max. biogas production (ml)	Max. m^3/kg COD reduced
1.	6.10	69.23	4472.7	0.51
2.	9.14	72.43	7700.0	0.56
3.	12.19	59.21	4653.1	0.31
4.	15.24	54.21	4466.8	0.26

Table 5. ANOVA single factor

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	0.17512	3	0.0584	10.65	0.001	3.49
Within groups	0.06578	12	0.0055			
Total	0.24089	15				

potential, which can be treated through biomethanation. The effective OLR, at which COD removal was significant was 9.14 gCOD/l/day. The maximum COD reduction at effective OLR was determined as 72.43% with biogas yield of 0.56 m^3/kg COD reduced (at normal temperature and pressure). The significant reduction in COD not only helped in reducing pollution load but will also generate a value added product i.e. biogas. The results showed that anaerobic digestion is an appropriate technology that can be applied to RCF industry.

REFERENCES

Bakraoui, M., Hazzi, M., Karouach, F., Ouhammou, B. and El Bari, H. (2019a). Experimental biogas production from recycled pulp and paper wastewater by biofilm technology. *Biotechnol. Lett.* **41**: 1299-1307. *doi: 10.1007/s10529-019-02735-w*.

Bakraoui, M., Karouach, F., Ouhammou, B., Aggour, M., Essamri, A. and El-Bari, H. (2019b). Kinetics study of the methane production from experimental recycled pulp and paper sludge by CSTR technology. *J. Mat. Cycles Waste Man.* **21**. *doi: 10.1007/s10163-019-00894-6*.

Bakraoui, M., Karouach, F., Ouhammou, B., Aggour, M., Essamri, A. and El-Bari, H. (2020). Biogas production from recycled paper mill wastewater by UASB digester: Optimal and mesophilic conditions. *Biotechnol. Rep.* **25**. *doi:10.1016/j.btre.2019.e00402*.

Bhatia, R. K., Ramadoss, G., Jain, A. K., Dhiman, R. K., Bhatia, S. K. and Bhatt, A. K. (2020), Conversion of waste biomass into gaseous fuel: Present status and challenges in India. *Bio Energy Res.* **13**. *doi.org/10.1007/s12155-020-10137-4*.

Chen, C., Liang, J., Yoza, B. A., Li, Q. X., Zhan, Y. and Wang, Q. (2017). Evaluation of an upflow anaerobic sludge bed (UASB) reactor containing diatomite and maifanite for the improved treatment of petroleum wastewater. *Bioresource Tech.* **2017.** *doi:10.1016/j.biortech.2017.06.17*.

Ekstrand, E. M., Hedenstrom, M., Svensson, B. H., Yekta, S. Shakeri and Bjorn, A. (2020). Methane potentials and organic matter characterization of wood fibres from pulp and paper mills: The influence of raw material, pulping process and bleaching technique. *Biomass Bioenergy* **143.** *doi.org/10.1016/j.biombioe.2020.105824*.

Fermoso, F. G., Serrano, A., Alonso-Farinas, B., Fernandez-Bolanos, J., Borja, R. and Rodriguez, G. (2018). Valuable compounds extraction, anaerobic digestion and composting: A leading bio refinery approach for agricultural waste. *J. Agric. Food Chem.* **66***:* 8451-8468. *doi.org/10.1021/acs.jafc.8b02667*.

Kamali, M., Gameiro, T., Costa Maria E. V. and Capela, I. (2016). Anaerobic digestion of pulp and paper mill wastes–An overview of developments and improvement opportunities. *Chem. Eng. J.* **298**: 162-182.

Reungsang, A., Sittijunda, S. and Sreela-or, C. (2016). Methane production from acidic effluent discharged after the hydrogen fermentation of sugarcane juice using batch fermentation and UASB reactor. *Ren. Energy* **86**: 1224-1231.

Sangeetha, A. and Sharmila, T. (2020). Hydrodynamic behaviour of a laboratory scale hybrid upflow anaerobic sludge blanket reactor. *Ind. J. Chem. Tech.* **26**: 161-165.