

Biomethanation of Alkaline-Sulphite Black Liquor : A Case Study

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ABSTRACT

The present paper describes a case study of biomethanation of alkaline sulphite black liquor generated from pulping of agro-residues viz. Sarkanda (Saccharum munja), kahi (Saccharum spontaneum), wheat straw (Triticum aestivum) and rice straw (Oryza sativa). Technical aspects and the factors observed to affect the biomethanation during startup and operation of biomethanation have also been explained. The evaluation of performance of the reactor and economy of operation revealed that the biomethanation of alkaline sulphite black liquor in an upflow anaerobic sludge blanket (UASB) reactor resulted in the generation of average 8000-9000 cubic meters of biogas with COD and BOD reduction to the tune of 45-48% and 72-80% respectively. Further, utilization of biogas in the boiler for generation of steam resulted in a direct net saving of Rs. 80.17 lacs per annum due to replacement of rice husk with biogas. The findings of the study will certainly encourage more paper mills to adopt the biomethanation technology for reducing the pollution load and generating the revenue from the waste as well.

INTRODUCTION

The pulp and paper industry has been put amongst 17 most polluting sectors by the Central pollution control board due to dominating nature of the pollution control problem in this particular sector. The major environmental issue associated with the paper industry at the moment is utilization of effluent generated in the process of paper manufacturing. While cooking the raw materials for pulp making, an effluent called "black liquor" is generated which raises an environmental threat, if left untreated before discharging the effluent. In this regard, agro based paper mills generate much higher pollution load than the large integrated wood and bamboo based paper mills due to non-utilization of spent black liquor for recovery of chemicals. The absence of a dependable and economical technology always remains a limiting factor while addressing this problem. However, now the paper mills have started to view beyond its customer to the interests of general public and no one actually wants to make money at the cost of environment, if a viable technology to upgrade the existing effluent treatment facilities is available.

In an attempt to find out a technologically suitable and economically viable option for the treatment of industrial waste, the anaerobic treatment for the

reduction of pollution load was introduced in late 70's in the form of anaerobic lagoons (1). Later on, the anaerobic treatment emerged as a viable option particularly for pulp and paper mills, (2-7) that resulted in about 84 full-scale anaerobic plants till 1998. Out of various anaerobic reactors available, biomethanation reactor based on Upflow Anaerobic Sludge Blanket (UASB) Technology is the most widely accepted installation for the effective anaerobic treatment of black liquor. Although the first UASB reactor was introduced in 1983, it is only few years back that this technology has gained considerable importance in pulp and paper sector. Unfortunately, the initial R&D finding in terms of toxicity of the sulphite black liquor for biomethanation limited the scope of this technology to the mills based on alkaline pulping process only. Even some mills have to change their pulping process from alkaline-sulphite to alkaline process to adopt this technology. However, advanced R&D efforts of ABC Paper in association with Department of Biotechnology, H.P. University, Shimla has made the biomethanation process technically feasible for alkaline sulphite black liquor (Fig. 1).

EXPERIMENTAL

Biomethanation Reactor in ABC Paper

ABC paper is an agro-residue based paper mill

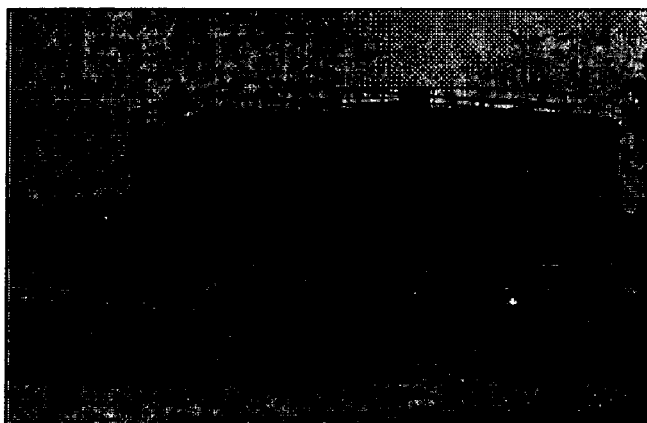


Fig. 1 UASB Reactor

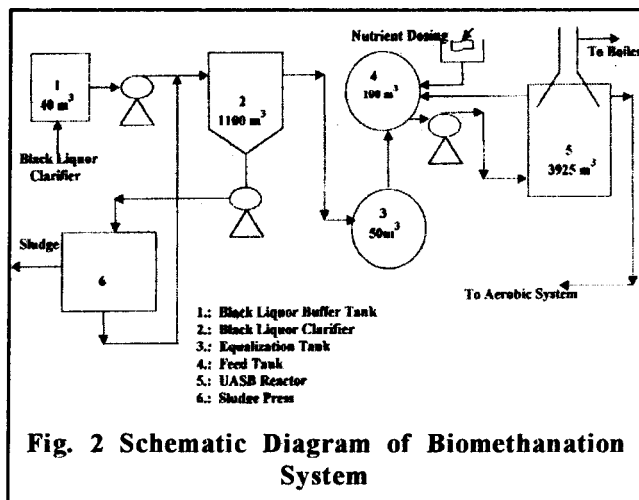


Fig. 2 Schematic Diagram of Biomethanation System

producing fine quality writing and printing paper from wild grasses viz. Sarkanda (*Saccharum munja*), Kahi (*Saccharum spontaneum*), Wheat straw (*Triticum aestivum*), Rice straw (*Oryza sativa*) and some proportion of waste paper using alkaline sulphite process. The characteristics of black liquor generated in the process are as follows:

Table 1 Characteristics of Alkaline Sulphite Black Liquor

Parameter	Limit
Total Solid Content	6-7%
Organic: Inorganic Ratio	72:28
COD	40-50 g/l
BOD	9-11 g/l
Chloride Content	900-1400 mg/l
Sulphite Content	850-1050 mg/l
pH	9.5-10.5

After studying the treatability of alkaline sulphite black liquor for biomethanation in laboratory scale UASB reactor fabricated in ABC workshop, a biomethanation reactor based on UASB technology with a volume and organic loading capacity of 3925 cubic meters and 12 kg COD/cubic meter/day was installed in December, 1999 for the treatment of alkaline sulphite black liquor. The biomethanation system at ABC paper includes following components:

Table 2 Components of Biomethanation System

Component	Capacity (m ³)
Black Liquor Clarifier	1100
Equalization Tank	50
Feed Tank	100
UASB Reactor	3925

The schematic diagram of the biomethanation system has been shown in Fig. 2.

Start-up and Stabilization of UASB Reactor

Initially at the time of the stabilization, the reactor was seeded with the inoculum from the distillery installations and cow dung. Later on, it was supplemented with commercial bioculture and also sludge from the anamet system operational at ABC Paper keeping in view the adaptability of the bacterial population of anamet sludge to black liquor.

The organic loading was started from 0.5 kg and increased gradually to 12 kg COD/cubic meter/d i.e. designed load over a period of about 8 months. It was observed that organic loading played an important load in stabilization of the system. Keeping in mind the slight variation in terms of the COD of the black liquor, the biomethanation reactor is kept at a loading of 11-11.5 kg. COD/cubic meter/d.

RESULTS AND DISCUSSION

Factors Affecting Biomethanation Process & Operational Problems

Biomethanation is a biological process involving degradation of organic fraction of waste water containing proteins, carbohydrates, lipids etc. in the absence of oxygen to methane, carbon dioxide and few other gases in traces. The process of biomethanation takes place in four successive degradation phases i.e. hydrolysis, acidification, acetogenic and methanogenic phase with the participation of several groups of microorganisms. The functionally different microbial populations in various phases of biomethanation process are metabolically dependent of each other in a way that the behavior of one type of bacteria may affect the

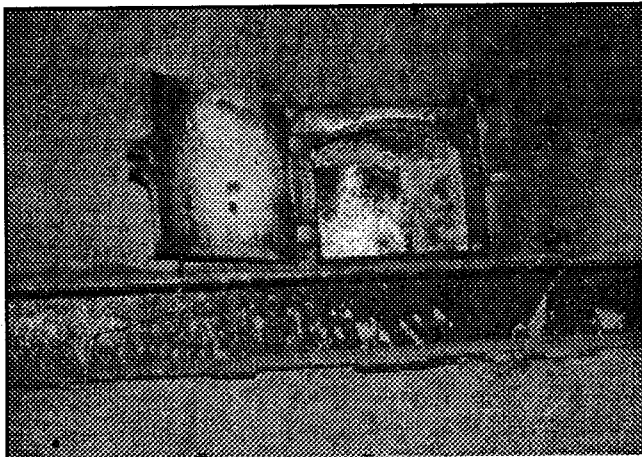


Fig. 3 Burning of Biogas in the Boiler

efficiency of the other. The bacteria involved in biomethanation are sensitive to a number of factors. The followings are the critical factors affecting biomethanation process observed during startup and operation of UASB reactor in ABC Paper.

Temperature

The temperature of the reaction mixture that in turn is affected by the atmospheric temperature affecting the growth and activity of the methanogenic bacteria at any given time. The optimum temperature for biomethanation process is 38-45°C. The acetogenic and methanogenic bacteria are sensitive to temperature with even 2-3°C drop affecting biogas production.

pH of Reaction Mixture

pH has a decisive role in biomethanation process due to sensitive nature of methanogenic bacteria towards variation in pH. The optimum pH for the biomethanation process is 6.8-7.5. A substantial variation above and below this pH range for more than 12 hours may affect the efficiency of the reactor.

Hydraulic Retention Time

Retention time i.e. the length of time elapsed between the time of feeding and coming out of the effluent from the reactor, also plays an important role in determining the degree of degradation of organic matter present in the effluent. However, the length of the retention time depends on the rate of decomposition under different reaction conditions like temperature that is affected by the atmosphere. Length of HRT is also decided on the basis of the physicochemical nature of feedstock viz. fats, oils, proteins carbohydrates, lignin etc. A hydraulic retention time (HRT) of 50 hours has been found to be optimum for the treatment of alkaline sulphite liquor.

Trace Elements

Some elements when used in traces like cobalt, nickel, iron, calcium etc. etc were found to enhance the efficiency of the system, the trace elements have been reported to accelerate the activity of methanogenic bacteria.

Other Factors

The supply of additional carbon source at the time of reactor stabilization type of seed inoculated, degree of variation in COD load applied to the reactor etc. also determines the degree of adaptation to a particular type of effluent and length of stabilization period.

Operational Problems

The major problem encountered during operation of the UASB reactor was the drop in temperature level below 35°C during winter months, which resulted in low efficiency of UASB reactor during that particular period. This problem was later on overcome by connecting a steam line to the feed tank of the reactor to raise the temperature of the influent to 45°C. This modification resulted in the stabilized performance of the reactor throughout year.

Performance of Biomethanation Réactor

The Biomethanation System at ABC Paper has been running satisfactorily for the 2 years. Performance of the reactor in terms of biogas production and reduction in pollution load has always been constantly monitored. The average reduction in COD and BOD achieved has been in between 45-48% and 72-80% respectively with average generation of approximately 8000-9000 cubic meters of biogas (Fig. 3) which is being utilized in boiler along with rice husk for generation of steam (Fig. 4).

Economy of Operation

The UASB reactor installed has resulted in

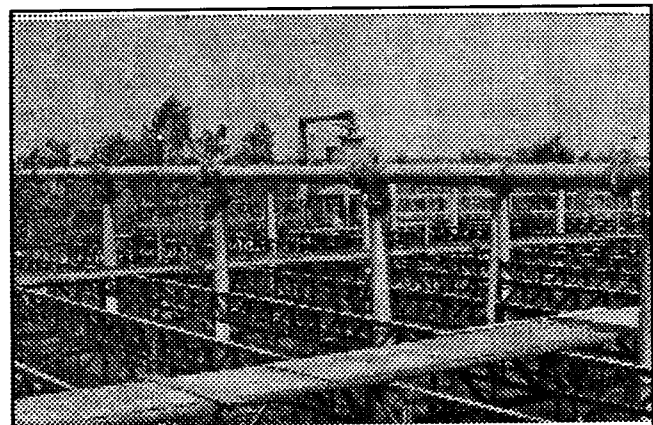


Fig. 4 Gas Collection and Defoaming system at the top UASB Reactor

reduction of pollution load in terms of COD and BOD on one hand and generation of revenue in terms of direct saving resulted due to replacement of a substantial quantity of rice husk with the gas produced in the reactor. Apart from this, the incorporation of biomethanation in the existing system has also resulted in the stabilization of the subsequent aerobic system and reduction in the consumption of nutrients in subsequent treatment. The economy of the operation of biomethanation system is demonstrated as follows:

Biogas generation / day : Average 8000 cubic meters
Equivalent rice husk replacement: 17 tonnes
(1000 m³ gas = 2.18 tonnes rice husk)
Cost of rice husk Rs 1750/tonne.

Direct saving due to rice husk replacement: Rs 29750/day i.e. Rs. 108.59 lacs/annum

Cost of steam required

During winter months: Approx. Rs. 12 lacs/year

Operation cost: Rs. 4500/day i.e. Rs. 16.42 Lacs

Net saving : Rs 80.17 lacs/annum

The availability of technology for the biomethanation of alkaline sulphite black liquor will certainly encourage more mills to come forward to adopt the technology for pollution abatement and utilization of waste for energy generation as well. Biotechnologists are now working on the pretreatment of black liquor with microorganisms like white rot fungi to degrade the biorefractory components like lignin to further enhance the efficiency of biorefractory components like lignin to further enhance the efficiency of biomethanation process for pulp and paper mill effluent, which will certainly help to improve the acceptability of biomethanation system for the treatment of paper mill effluent.

CONCLUSION

The biomethanation system has been proved to be a technically and economically viable option for the treatment of alkaline sulphite black liquor thereby making it suitable for the mills based on alkaline sulphite pulping without disturbing their existing process. The additional advantage of biomethanation of alkaline sulphite liquor is that the addition of acid to lower the pH to alkaline black liquor a critical step in operation of biomethanation system is

eliminated since the level of pH in alkaline sulphite always remains more or less within tolerance limit. However, the knowledge of fundamental processes involved in methane fermentation is necessary for optimum operation and monitoring of a biomethanation system.

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