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APPLICATION OF ALTERNATE ENERGY THROUGH GENERATION, PURIFICATION & UTILIZATION OF BIOGAS FROM PULP & PAPER MILL EFFLUENT

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Abstract:

In paper production, energy constitutes the major percentage of the total production cost. In recent times increasing coal prices, looming energy crisis due to Russia - Ukraine war / China- Taiwan tensions, pulp and paper mills are compelled to explore options for reducing energy bills so as to have competitive edge with domestic and international competitors.

One of the energy management route is to use / partially substitute conventional energy sources with alternate energy sources. Generation of bioenergy through bio methanation of mill effluent and its utilization as fuel / power generation is gaining interest among pulp and paper mills. A BIOPAQ® ICX biomethanation plant supplied by Paques has been recently installed and commissioned at Sainsons Paper Industries Pvt Ltd , Pehowa, Haryana to treat the raw material washings and paper machine excess water which has a good biodegradability potential. The plant is designed for handling 18000 kg COD per day and an effluent volume of around 4500 m^3/day. In last 1.5 years of its operation, the average COD reduction and biogas generation has been 65-70 % and >5000 m^3/day respectively.

Pretreatment by biomethanation has helped in reduction in pollution load being treated through conventional activated sludge process. The reduced pollution load has also reduced the energy consumption as well as chemical consumption in conventional activated sludge process. As the composition of bio gas generated is CH_4 65- 70 %, CO_2 >25% and H_2S <1%, further efforts are under progress by CPPRI , Knowledge Information Systems (KIS) ,Bengaluru to purify and compress the biogas up to 98 % methane concentration so that it can be used as an alternate fuel for vehicles / generation for electricity by Sainsons. For this a 3 ton per day CBG plant is being installed involving H_2S scrubber system of chelating ion technology and CO_2 removal by four tower Pressure Swing Adsorption System (PSA) . The mill has already entered an agreement with HPCL to sell the generated biogas post purification under Sustainable Alternative Towards Affordable Transportation (SATAT) scheme . The paper highlights the joint efforts by technical institution (CPPRI), Technology Suppliers (Paques / KIS) & Industry (Sainsons Paper Industries) for generation, purification and utilization of bioenergy.

Keywords: Biogas, CH_4, CO2, H_2S, COD, BIOPAQ® ICX, SATAT, PSAHPCL

Introduction:

The increasing cost of energy in recent times has adversely impacted the cost of paper production. As such there is a need for energy conservation . or exploring galternative sources of energy to ensure sustainability(1). One of the energy conservation route is to use / partially substitute conventional energy sources with alternate energy sources. Generation of bioenergy through bio methanation of mill effluent and its utilization as fuel / power generation is gaining interest among pulp and paper mills(2). Recently a biomethanation plant has been successfully installed and commissioned at Sainsons Paper Industries Pvt. Ltd , Pehowa, Haryana to treat the raw material washings and paper machine excess back water which has a good biodegradability potential. The mill is an agro based mill with a production capacity of around 350 tpd kraft paper using agro residues and waste paper . The mill has full -fledged ETP up to tertiary treatment system to treat the mill effluent. The mill has consent to utilize the treated effluent for irrigation and plantation only.

Biomethanation Plant

With increasing energy cost and with a view to further improve its treated effluent quality the mill explored various options before opting for biomethanation plant. The biomethanation plant is a third generation anaerobic reactor which has been incorporated as a pre -treatment step before conventional aerobic treatment for handling the raw material washings and paper machine back water . The anaerobic reactor is designed to biologically degrade organic pollutants in the wastewater into biogas. The major merits associated with BIOPAQ® ICX reactor are (3):

- Reduction of VFA in water loop to ensure odour free paper production.
- Co-generation of energy as biogas along with treatment of wastewater
- Reduction in pollution load to achieve environmental compliance
- Reduction of the operational costs of conventional ETP

The anaerobic conversion of COD into methane is a biological process which is carried by a mixed culture of anaerobic micro-organisms and the mechanism involves following major steps:

1. Acidification
2. Methane formation

During the acidification process large organic compounds are converted into volatile fatty acids (VFA) which are small organic molecules, mainly acetic acid. This acidification process does not significantly change the COD concentration itself, but just changes the composition of the COD. Large organic molecules are basically "broken" into smaller organic molecules, which subsequently serve as food for the methane producing micro-organisms. The schematic diagram of biomethanation plant is indicated in **Fig 1**

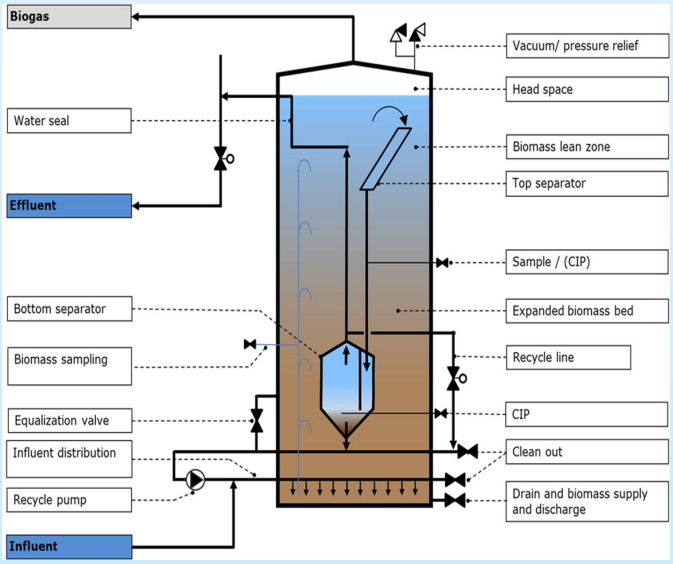

Fig 1 BioPaq ICX Reactor

The design specifications of biomethanation plant installed and commissioned at Sainsons paper Pvt Ltd . are indicated in **Table 1** and schematic diagram of biomethantion system is indicated in **Fig 2**

Table 1 Design Specification of Biomethanation Plant

S.No	Particulars	Value
1	Design COD Load , MT /day	18
2	Volume of Effluent , m^3 / day	4500
3	Velocity of Effluent , m/hr	5.3
4	Capacity of Conditioning Tank , m^3	375
5	Capacity of Bioreactor , m^3	1032
6	Height of Bioreactor, m	18.2
7	Hydraulic Retention Time , hrs	5.5
8	Biogas Generation , m^3 / day	6000
9	COD reduction %	65-70
10	Biogas generation per tonne of COD reduced, m^3	0.45

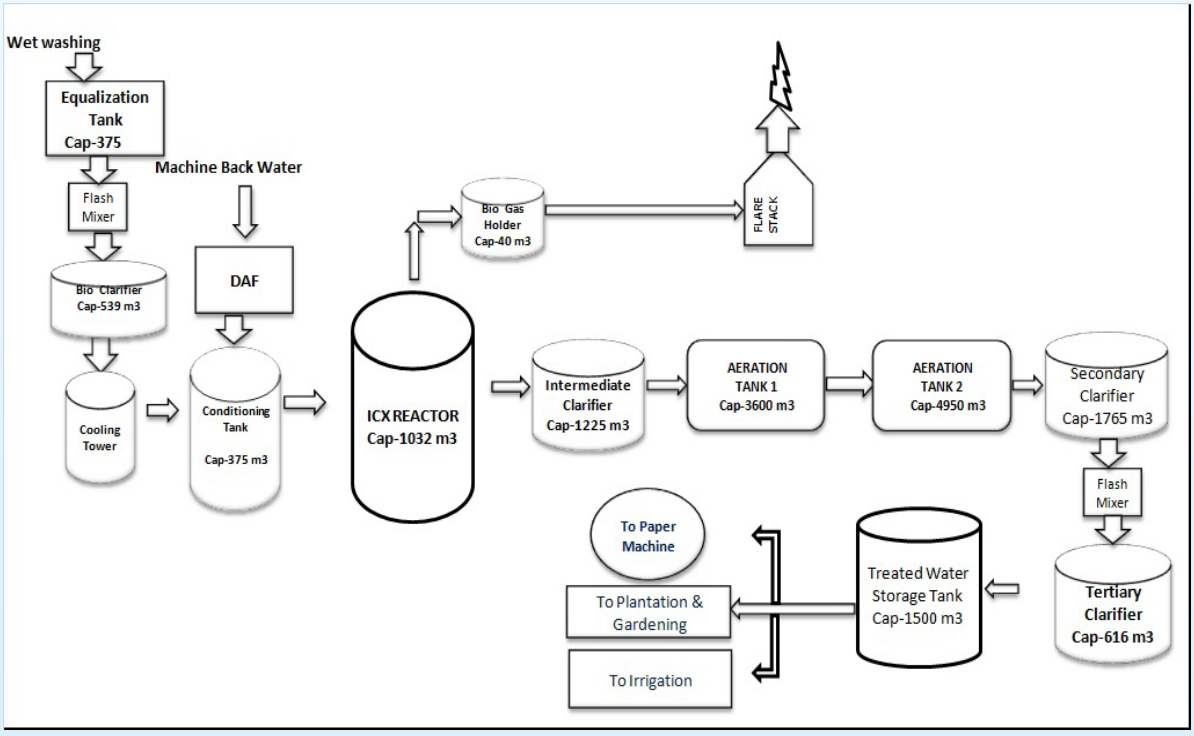

Fig 2 Schematic Diagram of Biomethantion System followed by Activated Sludge Process at Sainsons Paper Industries Ltd

The effluent from raw material washings is first clarified in Bio clarifier and the excess paper machine back water is treated through dissolved air floatation unit of the combined effluent is pumped into conditioning tank **(Fig 3)** where nutrients are added and pH, Temperature etc are maintained. The combined waste water is then treated anaerobically through Paques ICX reactor **(Fig 4)** . The biogas generated is stored in biogas holder to safeguard the reactor & to avoid any accident **(Fig 5)** and is further flared in the flare system continuously. (Fig 6)

Fig 3 Conditioning Tank

Fig 4 Bioreactor

Fig 5 Biogas Holder

Fig 6 Flaring of Biogas

Performance of Biomethnation Plant

The plant was commissioned initially with wet washing effluent in March 2021. During one year of its operation around 50 – 55%. reduction in COD was achieved. Since April 2022 ICX paper machine back water was also introduced into the system along with wet washings . The characteristics of waste water before and after biomethanation treatment and final discharge characteristics of treated effluent after post treatment of anaerobically treated waste water with other streams is summarized in **Table 2** The analysis was carried out as per Standard Methods for Examination of Water & Waste Water (6)

Table 2 : Performance of Biomethanation Plant

Parameters	Units	ICX Inlet	ICX Outlet	Final Discharge (after Tertiary Treatment)
pH	—	5.57	7.41	7.1
Temp	°C	37	36	25-28
TSS	ppm	422	531	10-15
COD	mg/L	4592	1276	180 - 200
BOD	mg/L	1600	700	15-18
Calcium	ppm	408	364	320
VFA	meq/L	31.2	BDL	-
Alkalinity	meq/L	6.78	32.74	-

The performance of ICX reactor at present with respect to COD reduction has improved up to 65 - 70% **(Fig 7)** and biogas generation around 6000 m^3/d.**(Fig 8)**

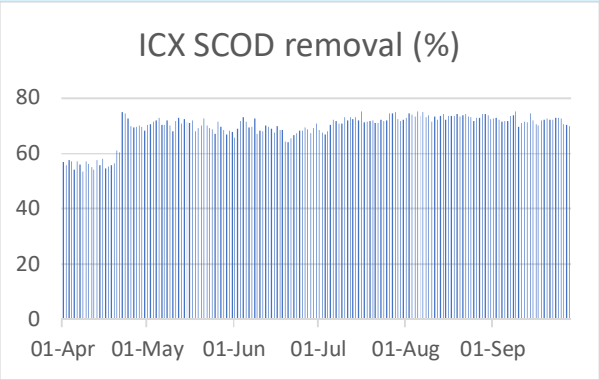

Fig 7 COD Reduction Profile of Biomethanation Plant

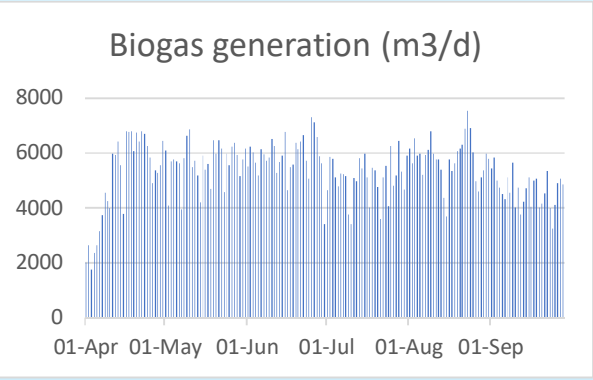

Fig 8 Biogas Generation Profile of Biomethanation Plant

Impact on Overall ETP Operation Cost after Installation of Biomethanation Plant

The incorporation of biomethanation plant as pretreatment before conventional aerobic treatment has helped in reducing the pollution load going to aerobic treatment leading to reduction in power consumption , chemical consumption and overall ETP operation cost as indicated in **Table 3**

Table 3 : ETP Operational Cost Without & with Biomethanation

ETP Operation Cost	ETP Inlet Flow	Chemical Cost	Power		Mech. Cost	Elec. Cost	ETP Laboratory	Misc.	Total Cost	Cost
Without / Before Biomethanation	KLD	Rs/Day	Rs/day	kWh/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/m3
	3833	128296	86912	12416	6184	4810	6893	11284	244379	63.75
After incorporation of Biomethantion Plant	KLD	Rs/day	Rs/day	kWh/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/m3
	3907	101674	37088	9272	6708	1361	2222	14301	163354	**41.81**

Way Forward - Purification & Application of Biogas Generated Compressed Natural Gas System

As the composition of biogas generated is CH_4 is 65 -70 %, CO_2 is 30-35 % H_2S is 1- 2%, further efforts are under progress to purify and compress the biogas up to 98 % methane concentration so that it can be used as an alternate fuel for vehicles / generation for electricity. For this a 3 ton per day capacity CBG plant supplied by KIS group , Bengaluru is being installed involving H_2S scrubber system of chelating ion technology (Fig 9) and CO_2 removal by four tower Pressure Swing Adsorption System (PSA) (Fig 10) The biogas will then be compressed to 250 bar by high pressure compressors and filled in cascades to send them at petrol pumps to be used as CBG in vehicles. The final product specifications will be adhere all the quality and safety guidelines as notified by Govt. of India for automobile fuel purpose (Fig 11). Around 200 kg / day of Sulphur will be produced through scrubbing of biogas which can be used as fertilizer,

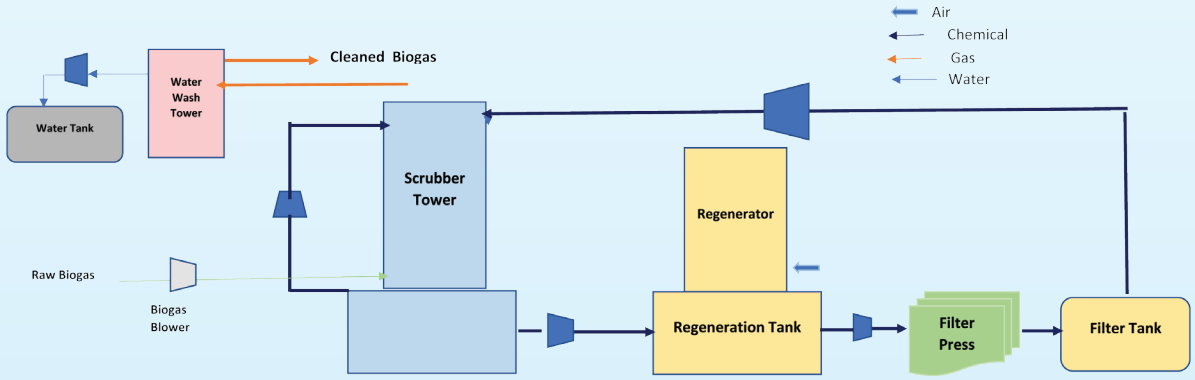

Fig 9 H_2S Scrubber System

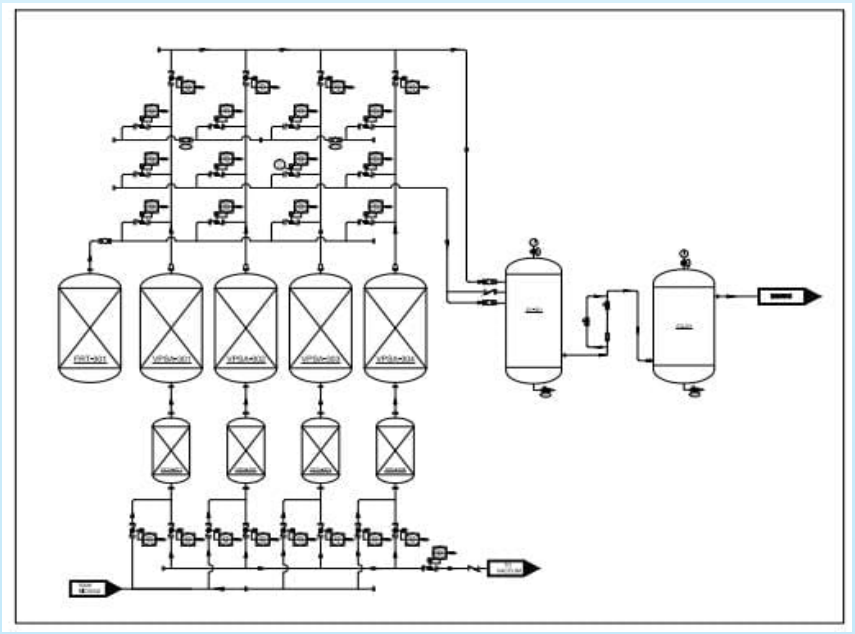

Fig 10 Four Towers PSA CO_2 Removal System

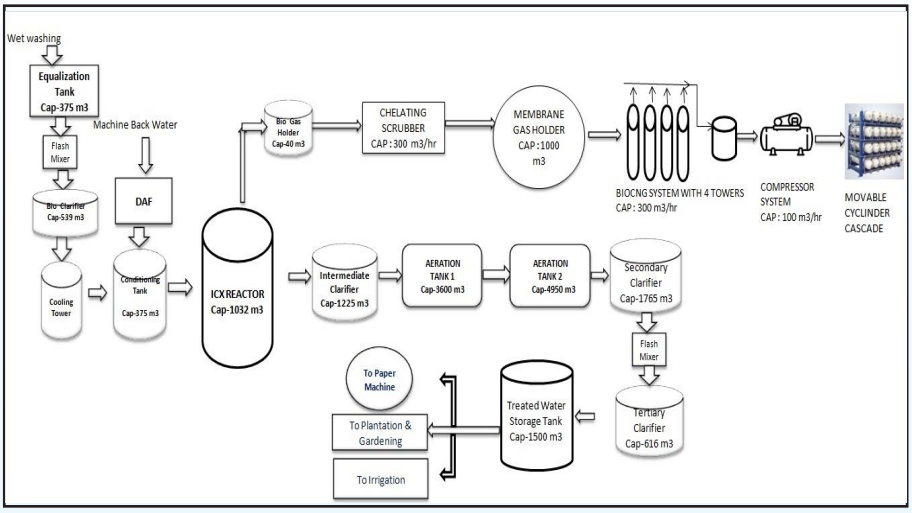

Fig 11 : Biogas Compression System

The mill has already entered an agreement with HPCL to sell the generated biogas post purification under Sustainable Alternative Towards Affordable Transportation (SATAT)

The techno-economics of Compressed Biogas Plant is summarized in **Table 4 (a) , (b) &(c)**

Table 4(a) Compressed Biogas Plant Estimated Operational Cost

Raw Biogas Flow	Compressed Biogas (CBG)	Chemical Cost	Power		Mech. Cost	Water Cost	Manpower Cost	Molecular Sieves	Total Cost	Cost
m3/Day	kg/day	Rs/day	Rs/day	kW/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/day	Rs/kg
6000	3000	7516	22470	3210	2220	2450	5332	24657	64645	**21.55**

Table 4(b) Compressed Biogas Plant Estimated CAPEX & OPEX

Raw Biogas Flow	CBG	Project Capex	OPEX	Total Opex	Operating days	Total Opex	Sale of Bio CNG	Total	
m3/Day	kg /day	Rs.	Rs./ day	Rs/day	Nos.	Rs/Year	Rs/kg	Rs/day	Rs/year
7200	**3196**	**70000000**	**22470**	**89488**	**330**	**29531040**	**54**	**172584**	**56952720**

Table 4(c) Return on Investment

Total Revenue	Total Opex	Net profit	Total Capex	ROI
Rs	Rs	Rs	Rs	years
56952720	**29531040**	**27421680**	**70000000**	**2.6**

In all conversion of raw biogas into compressed biogas looks to be a promising option in terms of low return on investment and profit earned thereof . Further taking average biogas generation as 6000 m^3 / day its utilisation / conversion to compressed biogas will help in reducing 157.75 kg / day (57736.5 kg/ annum) green house gaseous emissions (tons equivalent CO_2).

Conclusions

The biomethanation system has helped Sainsons Paper Industries Pvt Ltd not only in reducing the pollution load but has improved overall performance efficiency of the effluent treatment plant. The merits of ICX reactor are :

• Require less energy to degrade more organic matter compared to aeration basin

- Net production of energy in the form of methane (CH_4)
- Low emission of green house gas CO_2
- Reduction in footprint than conventional anaerobic treatment
- Net sludge generation is less, hence its handling and disposal cost is also less

The conversion of biogas generated into Compressed Biogas Gas will indeed be a significant step in improving the cost economics of the biomethanation plant as well as reducing the energy footprint. CPPRI (the Technical Institution) Paques India (the Technology Supplier- Biomethanation), Knowledge Integration System (the Technology Supplier- Compressed Biogas Plant) and the Industry (Sainsons Paper Industries Pvt . Ltd) are working synergistically for success of the project.

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