Combination of Anaerobic - Aerobic Proceses for Effective Treatment of Pulp and Paper Mills Effluents.

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Abstract

The medium and small size agro based mills which contribute more than 40% of total paper production are facing serious environmental problem after the implementation of CREP. These mills are now forced to increase their scale of operation to go to chemical recovery or to use recycled fibre in their fibre furnish. The agro based mills having scale of operation below 40 tpd are facing difficulty in adopting appropriate means to meet the environmental discharge norms. The combination of anaerobic - aerobic process has the potential for treatment of mill effluents to the reasonable discharge norms in a cost effective way. The combination of anaerobic - aerobic process for treatment of pulping spent liquor can save power consumption and chemical consumption to a level of 60% and 35% respectively, when it is compared with only aerobic treatment of pulping spent liquor to reduce the pollution loads to same extent. The present paper highlights the environmental issues, magnitude of pollution load and potential of combination of anaerobic and aerobic technologies for treatment of pulp and paper mill effluents discharged in agro based mills.

INTRODUCTION

Today the major concern is the energy and environment and paper industry is one of unique examples, which is highly energy intensive and polluting Industry. The Pollution loads especially from medium and small size mills where chemical recovery is not in practice, are basically high due to discharge of black liquor along with other waste waters while large pulp and paper mills are adequately equipped and have capacity to deal with pollution abatement. Due to increased public awareness and pressure from environmental regulating agencies, the treatment of effluents is now necessary in order to meet discharge norms. The medium and small size agro based mills which contributes more than 40% of total paper production are facing serious environmental problems and they are forced to look for appropriate methods for treatment of their wastewaters. The present practice of aerobic treatment i.e. activated sludge process is undoubtedly a most effective and widely used process for the removal of pollutants but this process suffers from major disadvantage of high operational cost due to relatively high requirement of energy and chemicals as nutrients and even by employing this process, it is difficult to achieve the discharge norms especially in mills where black liquor is discharged as effluents.

Anaerobic technologies due to development of high rate bioreactors and increased insight understanding of microbiology, limitations of anaerobes, the process is now widely recognised as proven technology even to treat pulp and paper mill effluents. Anaerobic treatment can be used as a pretreatment step which not only

converts the organic waste into useful bioenergy but also reduces the overall operational cost of subsequent aerobic treatment to reduce the pollution loads.

The present paper highlights the advantages and potential of combination of anaerobic and aerobic technologies for treatment of pulp and paper mill effluents to achieve reasonable discharge norms.

Environmental issues before agro based mills

The various process operations right from raw material handling to finished product, paper-manufacturing process exerts environmental pressure in one way or the other. The magnitude of pollution load generated from different agro based mills vary considerably and depends on the size of mill, raw materials used, process technology employed etc. Moreover among the pulp and paper sector the small and medium scale agro based mills are the major contributors towards the pollution load. With increasing public awareness and stricter environmental legislations coming into force, small mills are facing serious challenges for their sustenance and existence and as such environment compatibility has become the top agenda of these mills for their sustenance.

The major environmental issues associated with these mills which need immediate attention are-

•Discharge of pulping spent liquor in absence of chemical recovery system.

•High effluent loads.

•High level of colour in effluent.

•Discharge of high level of chlorinated phenolic compounds (AOX).

•Solid wastes disposal.

Magnitudes of pollution loads

The pollution load from agro based mills without chemical recovery is almost three times higher compared to large integrated mills. The pollution loads generated in small and large paper mills is given in Table-1.

The consumption of water in agro based pulp and paper mills vary from 175-225 m^3/tonne of paper, out of which about 90% is discharged, as effluent. The waste water is mainly generated from three sections i.e.:

Table -1 Characteristics and pollution loads generated from large and small agro based paper mills.

Parameters	Large integrated paper mill with recovery system	Agro based paper mills without recovery system
Flow, m^3/t paper	150-200	175-225
pH	6.5-9.5	6.0-9.0
SS, mg/l	800-1200	1000-1500
BODS at 20°C, mg/l	250-400	800-1200
COD, mg/l	800-1200	2500-4000
COD: BOD ratio	3.0-3.2	3.0-3.3
Colour, PCU	400-800	8000-12000
Pollution loads, kg/t paper:		
SS	160-180	250-400
BOD	40-80	150-250

- Pulp mill
- Bleach plant
- Paper machine

The pulping spent liquor is the highly polluted stream and it contributes more than 70% of total pollution loads. The treatment of pulping spent liquor is the major problem of mills. Since it contains lignin compounds (200-225 kg/tonne paper), which is almost biorefractory in nature. However pulping spent liquor contains an appreciable amount of biodegradable organic matter like carbohydrates, organic acids etc.

The bleach plant effluent also contributes significant amount of pollution load and is major source of pollution in large integrated mills. Bleach plant effluent is considered as the most toxic stream due to presence of chloro organic compounds formed during bleaching of pulp with chlorine containing chemicals. In India most of agro based pulp mill still continue the use of elemental chlorine for bleaching of high kappa no. pulp due to some economical reason which results in generation of high level of AOX compounds. The level of AOX in agro-residue based mills ranges from 3 to 7 kg AOX/tonne pulp. Therefore bleach plant effluent is not considered suitable for the treatment by anaerobic process. The only way to treat bleach plant effluent is aerobic treatment process.

The paper machine back water is comparatively less polluted and a major part of it is recycled after its clarification. The pollution load generated from three main sections are given in Table-2.

Status of anaerobic treatment technology

Due to recent development of high rate system, it has become possible to treat more complex pulp and paper mills effluents. The number of full scale plant are in operation to treat industrial effluents. Currently at least 33 full scale systems are in operation in pulp and paper industry. A great majority of existing anaerobic full scale plants are treating non-inhibitory forest industry waste waters rich in readily biodegradable organic matter such recycled fibre based mill effluent, mechanical and thermo mechanical pulping effluents.

Table- 2 Characteristics and pollution loads of major streams in agro based paper mills. (50 t/d)

Parameters	Different waste water streams		
	Pulping	Bleaching	Paper Machine
pH	8.0-10.00	6.0-7.5	5.0-6.0
Temperature, °C	50 - 60	30 - 40	30-40
Flow,m^3/d	4000-4500	3500-4000	2500-3500
Total Solids, mg/l	12000-15000	4000-6000	3000-4000
SS. mg/l	2500-3000	1500-2000	2000-3000
BOD, mg/l	3500-4500	800-1200	250-350
COD, mg/l	10000-14000	3000-4000	600-1000
Pollution loads generated:			
SS, kg/day	10000-13500	5250-8000	5000-10500
BOD, kg/day	14000-20250	2800-4800	625-1225
COD, kg/day	40000-63000	10500-16000	1500-3500

In last two decades, the Biomethanation technology has undergone tremendous changes especially in the design of reactor configuration to develop high rate bioreactors with compact size. The success of anaerobic processes is characterized by high concentration of active microorganisms in a reactor. A wide variety of process and reactor designs are available but the basic biology and biochemistry are of course the same in all implementations. The anaerobic reactors are primarily classified on the basis of the biomass immobilization methods and flow direction of wastewaters, which are:

Suspended growth system

In suspended growth system micro-organisms develop in the form of dense flocks or granules are retained in the reactor.

Attached growth system

The anaerobic microbes grow in colonies on fixed media or carrier material, which are provided. In this system the development & retention of anaerobic biomass is comparatively higher and is more resistant towards toxicity tolerance.

Some of the important high rate bioreactors based on different configurations and working on commercial scale described below.

Contact Process is a suspended growth system which consist of a completely mixed anaerobic reactor either with mechanical mixer or recycled biogas, Contact process tolerates high concentration of suspended solids, consequently it is widely used for treatment of sludge in addition to the treatment of liquid wastes. The process has in general a lower concentration of biomass and thus requires longer contact/ retention time and higher reactor volumes.

UASB Process is also a suspended growth system and microorganisms develop in well settling flocs or granules, consequently, the retention of biomass in reactor is very high. The wastewater is fed through specially designed distribution pipeline at the bottom. The key part of the reactor is a unique three-phase separator provided at the top of the reactor for separation of gas from liquid and sludge particles. The flow of wastewater and rising bubbles of biogas provide

Table- 3 The performance of anaerobic-aerobic treatment process for treatment of pulp & paper mil effluents

Parameters	Anaerobic Stage	Aerobic Stage	Overall Anaerobic-Aerobic
TMP Effluent (I):			
COD, Reduction, %	60-70	40-45	80-85
BOD, Reduction, %	70-85	65-85	>90
NSSC Pulp Mill Effluent (II)			
COD, Reduction, %	48-50	23-25	60-62
BOD, Reduction, %	70- 72	74-76	90-93
Semi Chemical Pulping Effluent (III):			
COD Reduction, %	57 -59	17-20	64-66
BOD Reduction, %	90-92	54-55	94-96
Kraft Evaporator Condensate (IV):			
COD Reduction, %	62-64	66-68	82-84
BOD Reduction, %	73-75	92-94	96-98

natural mixing & thus enhance the contact between wastewater & anaerobic microbes. The process can tolerate fairly high concentration of suspended solids without any clogging problem but these suspended solids may accumulate in the reactor & lead to the wash out of active biomass.

Expended Granular Sludge Bed Reactor (EGSB) is a modification of UASB reactor in which granular bed is expanded by applying high hydraulic flow velocity and high organic loading rates resulting in increased bio-mass activity and contact between biomass & organic wastes however high recirculation required to expan granular bed consumes high energy compared to UASB reactor.

Internal Circulation Reactor (IC) is also a modification of UASB process, consists of EGSB & UASB compartments on the top of each other. The special feature of the reactor is biogas separation in two stages. Whereby the gas collected in the first stage drives a gas lift & internal waste water biomass circulation and the later reduces the energy demand of the process. The technical start up of this process requires an external gas supply to the reactor.

Hybrid Reactor is a combination of UASB and upflow fixed film reactor. In this process, the lower part of reactor (30-50%) is the UASB portion where flocculent or granular sludge develops and upper part of reactor (50-70%) is the upflow fixed film which provides larger surface area for the development of mixed film of active biomass. The system has advantages of both UASB & fixed film reactors.

Table- 4 Anaerobic biodegradability of various substrates generated in pulp & paper sector

Subtracts Biodegradability,	Anaerobic %
Pulping spent liquor	6
- Wheat straw	50-60
- Rice straw	45-54
- Bagasse	40-52
Prehydrolysis liquor	85-80
Bagasse washings	80-85
Evaporator condensate	70-80
Recycled fibre mill effluent.	60-65

The contact and UASB process are most widely applied system for treatment of Industrial effluent. In India, one full scale anaerobic plant based on contact process is already working for treatment of pulping spent liquor from agro residues and performance result claimed by mills

Table-5 Performance results of combination of anaerobic-aerobic treatment of agro residues mills effluents generated in agro based mills.

Parameters	Anaerobic			Aerobic			Overall Anaerobic-Aerobic
	Clarifier	Anaerobic Reactor	Total	Clarifier	Activated Sludge Process	Total	
BOD removal, %	10	75	77.5	10	90	91	95
COD removal, %	15	40	49	10	40	46	67
Suspended Solid removal, %	60	40	76	80	70	94	95

Table-6 The expected characteristics of anaerobic- aerobically treated effluent:

pH	6.5-7.5
Temperature °C	25-35
BOD, mg/l	60-80
COD, mg/l	1725-2300
Suspended Solids, mg/l	75-110

are satisfactory. The other two full scale demo plant based on UASB technology are operating satisfactory for treatment of agro based pulping spent liquor and bagasse washings and functioning well at their designed loads.

Need for post treatment i.e. aerobic treatment

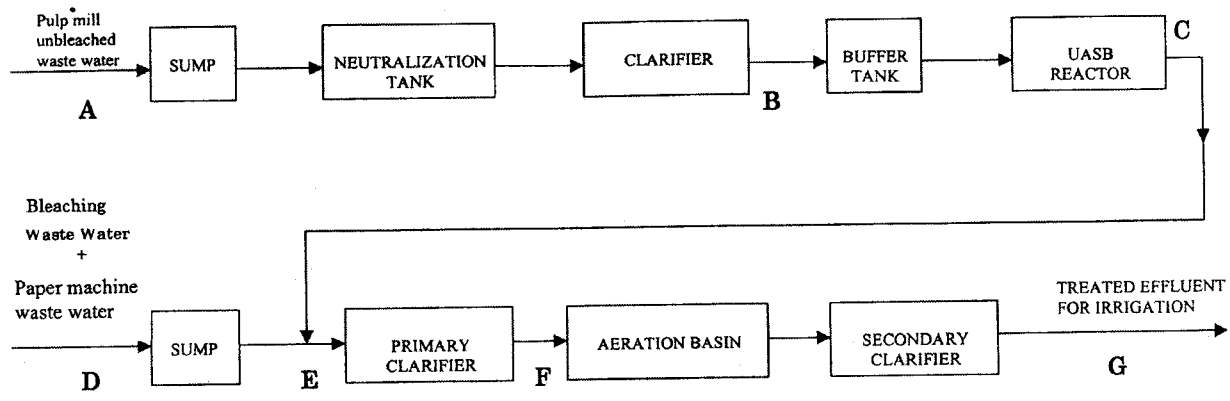
The anaerobically treated effluent contains traces of methane and H_2S, which is toxic to aquatic life. Secondly the single anaerobic treatment step is not sufficient to treat waste water to acceptable discharge norms. The post treatment of anaerobically treated effluent is necessary to reduce further pollution loads as well as for conditioning of anaerobic all treated effluents.

The overall performance of combination of both stages used for treatment of different type of waste water is given in Table-3.

The data reported in Table 3 clearly indicate that the combination of anaerobic & aerobic is a potential technology for treatment of wastewater particularly in agro based small mills.

Studies carried out at CPPRI

An extensive R & D studies are carried out at CPPRI to assess the anaerobic biodegradability of pulping spent liquors from wheat straw, rice straw and bagasse as well as other substrates generated in large mills in sufficient quantity. The potential of different anaerobic technologies for treatment of mill effluent in pulp and paper sector are also assessed. The anaerobic



CHARACTERISTICS OF WASTE WATER AFTER DIFFERENT STAGES OF TREATMENT

PARAMETERS	A	B	C	D	E	F	G
Flow, m³/day	4000-4500	3800-4300	3800-4300	6000-7500	9800-11800	9800-11800	9800-11800
BOD, mg/l	3500-4500	3150-4050	800-1 000	575-800	650-875	575- 775	60-80
COD, mg/l	10000-14000	8500-11900	5000- 7000	2000-2600	3200-4250	2800-3800	1700-2300
Suspended solids, mg/l	2500-3000	1000-1200	600- 725	1700-2500	1275-1825	250-375	75-110

Figure: 1. SCHEMATIC DIAGRAM OF ANAEROBIC - AEROBIC TREATMENT OF AGRO BASED MILL EFFLUENT

Table-7

Operational expenses & cost benefits of aerobic and anaerobic-aerobic treatment process:

Details	Aerobic	Anaerobic + Aerobic
Black liquor flow,m"/d	4000	4000
COD load/d	53000	53000
BOD load, kg/d	17000	17000
BOD, to be removed	17000	12750 (Anaerobic) .. 4250 (Aerobic)
Power requirement:		
-0.2 kwh/kg BOD removed (Anaerobic)	--	2550
-1.2 kwh/kg BOD removed (Aerobic)	20400	5100 7600
a. Power Cost, Rs.lday (3.50 Rs. Kwh)	71400	26775
Nutrients requirement: (Aerobic 100 : 5 : 1) (Anaerobic, 100 : 2.5 : 0.5)		
Urea kg/d	1500	950
DAP kg/d	800	530
Total, kQ/day	2300	1480
b. Nutrients cost, Rs/day (7.5 Rs./kg)	17250	11100
BOD Removal, %	90-92	95-97
Biogas generation, m"/day CV - 6200 K cal/m3	--	12000
Equivalent		
BioQas, K cal/day	--	74 million
- LSHS Oil (10,000 k cal/kg)	--	7.4 ton
c. Cost of Oil (6000 Rs/ton)	--	44400
Total Operational Cost [c-(a+b)]	- 88650	+ 6525
Net benefit for anaerobic aerobic treatment Rs./day	--	95550
Annual Benefit	**95500 x 330 = 315.15 lac**	

biodegradability of various substrates generated in pulp & paper sector are given in Table - 4.The data based informations generated at CPPRI on anaerobic biodegradability, anaerobic technologies, configuration, optimization process conditions have resulted the demonstration of anaerobic technology on mill scale for treatment of black liquor in agro based mills. CPPRI has been extending expertise and technical services to the mills intending to go for Biomethanation plant for treatment of pulping spent liquor etc.

The laboratory studies conducted on potential of anaerobic-aerobic processes for treatment of pulping spent liquor from agro residue indicate that the combination of anaerobic-aerobic process is effective in reducing the pollution loads i.e. BOD, COD and SS by 95%, 67% and 95% respectively Table-5. A schematic layout for anaerobic-aerobic treatment plant for agro based mill is shown on Fig. 1 alongwith the characteristics of wastewaters after different stages of treatment.

The characteristics of final discharge by employing combination of anaerobic-aerobic treatment are given in Table-6.

Cost benefit analysis

The cost benefit analysis for combination of anaerobic-aerobic over conventional method for treatment of chemical pulping spent liquor was worked out for 50 tpd mill using agro residues (Table-1) which indicate that application of anaerobic-aerobic treatment process offers savings in power consumption and chemical consumption in a tune of 60% and 35% respectively. Through biogas recovery the complete operation cost in terms of electrical power and chemical cost can be met out with some savings which can offer a pay back of investment from a non productive unit like Effluent Treatment Plant (ETP).

CONCLUSION

With the implementation of charter on Corporate responsibility for environmental protection (CREP) for pulp and paper industry, the survival of small scale agro based mills has become difficult particularly for those mills which have scale of separation below 50 tpd. Since law scale of operation restrict these mills to have chemical recovery system. In this perception, the effective combination of anaerobic-aerobic technologies may be a potential technology for treatment of their mill effluent in order to cope the emerging environmental issues and also for their sustained survival. One of the major advantage of combination of anaerobic aerobic process is recovery of bioenergy in addition to reduce the overall operating cost of effluent treatment plant. The successful performance of biomethanation plants operating in agro mills have increased the awareness & confidence in small agro based mills to go for biomethanation process in combination with conventional aerobic process.

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