Improved Effluent Treatment Process in an Agro-Based Paper Mill

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Abstract

The present paper is a case study of the performance of effluent treatment plant in a 72 TPD agro based paper mill without chemical recovery, wherein the effluent treatment process has been analysed both qualitatively and quantitatively. Activated sludge treatment has always been a conventional treatment for the paper mill effluent but it has been proved over a period of time that prescribed limits of pollution parameters could not be achieved with conventional treatment alone. The performance of effluent treatment plant based on activated sludge process for reducing BOD, COD and suspended solids from agro-based paper mill effluent has been explained in this study. The successful demonstration of application of high rate anaerobic systems for treatment of paper mill effluent has made it possible to enhance the efficiency of conventional treatment systems. The present study summarizes the improved performance of an effluent treatment plant by successful application of two most accepted high rate biomethanation systems viz. Anamet based on anaerobic contact process and UASB (Upflow Anaeronic Sludge Blanket) System for the treatment of agro-based black liquor. An evaluation has also been made on the effect of various operating parameters and corrective measures at different stages of effluent treatment process. The technological and economical suitability of a combination of high rate biomethanation system with conventional treatment for achieving the prescribed limits of pollution parameters in an agro-based paper mill and application of treated effluent in irrigation for different crops have also been explained. Lastly, the scope of further improvement in the exiting effluent treatment process is also discussed briefly.

INTRODUCTION

The treatment of effluent generated during paper manufacturing has always been a subject of study for researcher and industry as well to minimize the discharge of pollution load in the surrounding environment. ABC paper mill located at the Village Saila Khurd, Distt. Hoshiarpur, Punjab has been involved in the production of bleached cultural varieties of writing and printing paper out of annually renewable agro-residues such as Sarkanda grass (Saccharum munja), Wheat Straw (Triticum aestivum), Kahi Grass (Saccharum spontaneum), Rice Straw (Orvza sativa) etc. along with some quantity of waste paper for the last more than 20 years. The cooking process is alkaline-sulphite i.e. The cooking chemicals currently being used are Sodium Hydroxide (NaOH) and Sodium sulphite ($Na_2 SO_3$). The bleaching sequence is XC-Ep-H i.e. Enzyme pre-bleaching, Chlorination, Alkali Extraction & Hydrogen peroxide and finally Hypo-Chlorite bleaching.

Initially, the mill was set up for production capacity of 30 TPD. Later on, the production capacity was increased to 80 TPD and effluent treatment plant was installed based on conventional activated sludge process. But over a period of time, it was observed that only conventional treatment was not enough to meet the standards prescribed by pollution control boards. Therefore, a number of modifications such as incorporation of high rate biomethanation reactors

and other improvements were made in the effluent treatment plant for improving the efficiency of effluent treatment process.

To assess the performance of modified Effluent Treatment Plant (ETP) in meeting the limits prescribed for discharging treated effluent by State Pollution Control Board, a detailed study was conducted in association with Aman Biotech (India) & Research Laboratories, Chandigarh.

EXPERIMENTAL

To study the adequacy of the ETP at ABC Paper, all the details were collected regarding sizes & capacity of different ETP components. The flow of effluents was measured and the adequacy of the ETP to treat the volume and load of effluent being generated in ABC Paper was calculated. To assess the performance of ETP, composite samples from different stages of effluent treatment plants were collected and analysed for various parameters applicable for paper mill effluent.

Present Effluent Treatment Process in ABC Paper

In ABC Paper, the waste generated from various mill unit operations is segregated into two effluent streams i.e. highly polluted black liquor generated in the pulp mill and less polluted balance water stream containing bleach plant effluent & paper machine back water. The average volume of black liquor and the balance water recorded @1286 m^3/ day and 8710 m^3/day respectively at the time of visit.

The effluent treatment plant in ABC Paper consists of a UASB Biomethanation reactor for treatment of black liquor, two anamet reactors for treatment of black liquor in excess of the quantity that is being treated in UASB reactor, facultative aerated lagoon for treatment of anaerobically treated black liquor and balance water and four clarifiers at different stages for separation of suspended solids from effluent.

Therefore, the effluent treatment process in ABC Paper is a combination of conventional activated sludge treatments and high rate biomethanation and follows anaerobic-aerobic treatment after primary sedimentation for removal of suspended solids from the effluent in the clarifiers as shown in Fig 1. The sludge settled in the primary clarifiers is dewatered in a sludge filter press followed by natural drying and finally sold to paper-board manufacturers. The brief description of different treatment stage in ETP of ABC Paper as observed during the visit is as follows:

Primary Treatment of Black liquor

Primary Black Liquor Clarifier: The black liquor discharged from the brown stock washers is passed

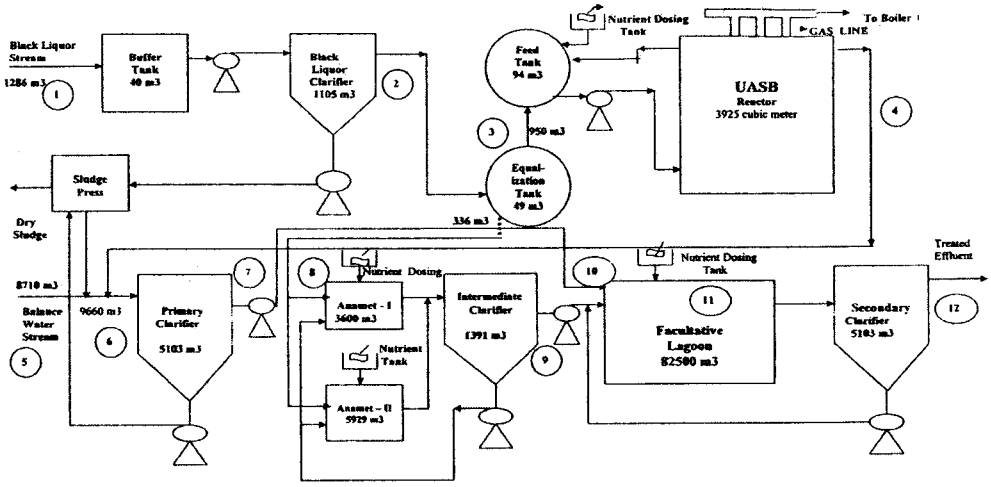

Fig.1 Flow diagram of effluent treatment process in ABC paper

through a primary black liquor clarifier to remove suspended solids.

UASB Reactor: The major portion of clarified black liquor is fed into the Biomethanation reactor on UASB technology. The remaining Black Liquor in excess of the quantity that is being treated in UASB reactor is treated in other anaerobic system of Effluent Treatment Plant.

Anamet: The excess black liquor is treated anaerobically in Anamet, an anaerobic system based on anaerobic contact process.

Intermediate Clarifier: The treated combined effluent from Anamet is passed through an intermediate clarifier. The sludge settled in the clarifier is recirculated back in the Anamet and the clarified effluent is further treated in the secondary treatment system of Effluent Treatment Plant.

Primary Treatment of Combined Effluent

Primary Clarifier: The combined effluent comprising of treated effluent from the UASB reactor and balance water generated in the bleach plant, paper machine etc. is passed through a Primary Clarifier for removal of fibre and other suspended solids.

Sludge Press: The sludge which is settled in the primary clarifier is dewatered by passing through a sludge filter press. The dewatered sludge is dried naturally and stored in the sludge storage pits & finally sold to paper-board manufacturers. The decanted water from the sludge press comes back to primary clarifier

Secondary Treatment of Combined Effluent

Aerobic Lagoon Facultative Aerated Lagoon: The anaerobically treated black liquor from intermediate clarifier and the combined effluent from primary clarifier consisting of overflow of UASB Reactor & balance water are treated aerobically in the aerobic lagoon/facultative lagoon.

Secondary Clarifier: The treated effluent from the aerobic lagoon is passed through a secondary clarifier to remove active biomass. The biomass settled in the clarifier is recirculated back in the aerobic lagoon to maintain the level of active biomass required by the system. The clarified treated effluent is discharged for irrigation. The sizes and capacities of different components of effluent treatment plant in ABC paper are as follows:

1. Primary Clarifier
   Diameter: 38 meter
   Depth : 4.5 meter
   Capacity : 5103.5 m^3
2. Black Liquor Clarifier
   Diameter : 16 meter
   Depth : 5.5 meter
   Capacity : 1105.8 m^3
3. UASB Reactor
   Diameter : 25 meter
   Depth : 8 meter
   Capacity : 3926.6 m^3
4. Anamet 1
   Size : 30x30x4 meter
   Capacity : 3600 m^3
5. Anamet 2
   Size : 38.5x38.5x4 meter
   Capacity : 5929 m^3
6. Intermediate Clarifier for Anamets
   Diameter : 22 meter
   Depth : 3.66 meter
   Capacity : 1391.2 m^3
7. Facultative Aerated lagoon
   Size : 100x150x5.5 meter
   Capacity : 82500 m^3
   Aerators : 14 Nos. each of 25 HP
8. Final Secondary Clarifier
   Diameter : 38 meter
   Depth : 4.5 meter
   Capacity : 5103.5 m^3

RESULTS AND DISCUSSION

The results of analysis of samples collected at various stages of effluent treatment plant have been summarized in Table 1.

Black Liquor Clarifier

The average flow of black liquor in the black liquor clarifier was recorded as 1286m^3/day. The surface loading for black liquor clarifier having a diameter of 16 meter with this much quantity of black liquor works out to be 7.28 m^3/m^2/day which is almost 1/4th of the lower limit of surface loading range of 30-60 m^3/m^2/day and hence is sufficient enough

Table1: Analysis Results of Effluent Samples

Point of Sample Collection	pH	TSS mg/l	COD mg/l	BOD mg/l	MLSS mg/l	MLSS mg/l	SAR
Inlet of Black Liquor Clarifier/Raw Black Liquor	10.7	21340	53200	12945			
Outlet of Black Liquor Clarifier	9.85	10820	41360	9987			
Inlet to UASB Reactor	9.85	10820	41360	9987			
Outlet of UASB	7.9	1370	21265	2460			
Balance Water	6.9	1200	1510	480			
Inlet of Primary Clarifier	7.15	1250	3110	610			
Outlet of Primary Clarifier	6.6	540	2215	405			
Inlet of Anamet	9.85	10820	41360	9987			
Outlet of Intermediate Clarifier	7.62	510	21015	2330			
Inlet of Aerated Lagoon	7.1	515	2350	445			
Facultative Aerated Lagoon					3260	1795	6.3
Outlet of Sec. Clarifier	7.39	91	675	88			

Table 2: Evaluation of UASB Reactor in ABC Paper

Parameter	
COD of Black Liquor fed in the reactor	41360 mg/l
BOC of Black Liquor fed in the reactor	9987 mg/l
Reactor Volume :	3925m³
Designed Organic loading Rate :	12 Kg. COD/m³/day
Black Liquor flow in the Reactor :	950m³/day
Current Organic Loading Rate :	Approx 1.0 Kg. COD/m³/day
Hydrolic Retention Time (HRT)	50 h.
pH of the Reaction Mixture	7.52
Temperature of the Reaction Mixture	39.8°C
Volatile Fatty Acids	69meq/l
Alkalinity	148 meq/l
COD Removal Efficiency	48.58%
BOD Removal Efficiency	75.36%

to take care of this quantity of black liquor. The S.S. removal efficiency of the black liquor clarifier was found to be 49.2%. whereas the BOD and COD removal efficiency of the black liquor clarifier was calculated to be 23.0% and 22.25% respectively.

UASB Reactor

The operating parameters and evaluation of the analysis have been summarized in Table.2. The capacity utilization of UASB Reactor currently being operated at a loading rate of approx. 10 kg. COD/ m³/day has been found to be 83.3%. The ratio of VFA to alkalinity was found to be 0.46 which indicates satisfactory operation of the reactor. The BOD and COD removal efficiency of UASB reactor

has been calculated to be 75.36% and 48.58% respectively. The relatively low COD eduction may be due to the presence of lignin which contributes towards more than 50% of the COD in the black liquor and moreover the high molecular weight fraction of which is not degradable anaerobically. A number of reports are available in literature on the suitability of UASB reactor for the treatment of waste water from paper mills.

According to Vuoriranta et. al (1) stability of anaerobic process is difficult to maintain at higher loadings. Further, if the activated sludge process/ aerobic system following the anaerobic system is not overloaded, the temporary failure in the anaerobic process could be compensated to a extent to keep the quality of final effluent reasonable. Keeping in view the above fact, higher capacity of the Aerobic Lagoon in ABC Paper is advantageous.

Mehner et. al (2) studied the treatability of waste water from a Kraft pulp, paper and board mill in Activated sludge process, UASB reactor and Combined Treatment. Results of the study revealed that 80% COD removal could be achieved in activated sludge process and in combined treatment. It was also reported that anaerobic treatment in an USAB reactor alone caused a 50-70% COD reduction. Based on this study it was concluded that difference in the COD removal efficiency was due to presence of lignin compounds making up around 1/3 of the Waste water from thermo-mechanical pulp waste water used in the study.

Evaluation of the treatment of sulphate containing organic waste water from a paper manufacturing process in UASB reactor has shown that after acclimatization of bacterial sludge, COD removal rate to the tune of 80% could be achieved with a loading rate upto 26 Kg/cu.mtr./day (3).

A study on the treatment of Soda pulping waste water from a paper mill have shown that soda pulping waste water in inhibitory to the methanogens particularly in wood based mills. However, it was found that if the waste water is diluted to subtoxic level with less toxic stream, anaerobic treatment could be made feasible in the soda based black liquor. COD removal efficiency reported in study was 40-50% for soda pulping liquors (4).

Repeti (1991) have studied the treatment of industrial waste with high organic content in the UASB reactor for the production of methane at optimum conditions of 32-38 degree celsius temp. and pH 6.8-7.8. It was revealed that conversion rate upto 85% could be achieved in the UASB reactor. Studies based on thermophilic anaerobic digestion of hot sulphate rich paper mill effluent in UASB reactor have shown 55% COD removal efficiency at the loading rate of 41 Kg. COD/cu.mtr./day (5).

Preteatment of waste water from an Austrian paper mill in a full scale anaerobic-aerobic pre-treatment plant with an UASB reactor has confirmed the suitability of the combination of high rate bio-methanation system with the convention effluent treatment system for the treatment of paper mill effluent. Total COD removal reported in the study is in the range of 80% (6)

Rintala and Lepisto (7) have evaluated the treatment of thermo-mechanical pulping waste water in UASB reactor and other anaerobic systems at different temperatures ranging from 35 degree celsius to 70 degree celsius. In UASB reactor, upto 65-75% COD removal was obtained at 55 degree celsius at loading rates of 12-22 Kg COD/cu/mtr/day. Even at a loading rate of 80 kg. COD/m^3/day, about 60% removal was maintained at 55°C.

A Study on the treatment of alkaline black liquor from cereal straw pulping mill has shown that lignin and lignin related compounds inhibitory to the anaerobic process could not be degraded but partly absorbed by anaerobic biomass. The UASB digester used in the study achieved 50-60% COD removal efficiencies at loading rates of 5-10Kg. COD/cu.mtr/day (8).

The various literature reports therefore, confirm the suitability of the UASB system for the treatment of black liquor if operated under controlled condition with careful monitoring to reduce the pollution load to a substantial level, the need of an effective aerobic treatment system following the aerobic system can not be ruled out for complete treatment of the effluent since, the anaerobic system alone can not bring the level of pollution load down to the prescribed limits of standards.

Though, UASB reactor can handle a load of 10-

30 kg. COD/m³/day, but has very low tolerance for high levels of insoluble COD. Further, sometimes the deposition of lignin on the active biomass prevents its contact with the effluent thereby reducing treatment efficiency. Biomethanation in an UASB reactor is temperature sensitive process therefore, reduction in the efficiency of the reactor is observed during winter season if not provided with temperature control system. In ABC Paper, it was observed that a steam line has been provided in the feed tank of the UASB reactor so as to maintain the temperature of the influent at the desired level during winter.

There are many reports in literature on treatment of different types of effluents including paper mill effluent where UASB reactors designed for 10-12 kg. COD/cu.mtr.day have been used to treat the effluent at a loading rate of upto 80 kg COD/cu. mtr./day with minor reduction in the COD/BOD removal efficiency (9).

Anamets (Anaerobic Contact Process)

The operating parameters and the evaluation of the performance of Anamets have been summarized in Table 3. In Anaerobic Contact Process, untreated waste water is introduced and completely mixed with contents of the reactor. The hydraulic retention time in the anamet reactor are very high in comparison to UASB Reactor. After this, the contents of the reactor are passed through a solid separation process such as clarifier from where the settled sludge is recycled back into the reactor and the overflow of the clarifier is treated in the subsequent aerobic system. The efficiency of the anamet reactors was found to be quite comparable to the UASB reactor. The capacity utilization of anamet reactors is only 30% which means that more than three time of the existing black liquor volume may be easily treated in the amanet reactors. The temperature of the reaction mixture was found to be 36.5°C which is will within the required limit of 35-45°C for anaerobic reactors. The temperature of the reaction mixture is somewhat lower than UASB reactor probably due to longer retention time in the anamet reactor. the ratio of volatile fatty acids to alkalinity was found be 0.41 which is satisfactory.

Intermediate Clarifier

The black liquor after treatment in the anamet reactor is passed through an intermediate clarifier to separate the active biomass for recirculation back into the anamet reactors. Currently, a volume of approximately 350 m³/day is being passed through the clarifier having a diameter of 22 meters. The surface loading of the clarifier with 350 m³ of black liquor comes out to be approx. 1m³/m²/day with a retention time of 4 days.

Table 3: Evaluation of Anamet Reactors in ABC Paper

Parameter	
COD of Black Liquor fed in the reactor	41360 mg/l
BOC of Black Liquor fed in the reactor	9987 mg/l
Reactor Volume :	Anamet 1: 3600 m³ Anamet 2 : 5929 m³ Total : 9529 m³
Designed Organic loading Rate :	5 Kg. COD/m³/day
Black Liquor flow in the Reactor :	336 m³/day
Current Organic Loading Rate (OLR) :	Approx 1.5 Kg. COD/m³/day
Hydrolic Retention Time (HRT)	28 days
pH of the Reaction Mixture	7.85
Temperature of the Reaction Mixture	36.5°C
Volatile Fatty Acids	62meq/l
Alkalinity	151 meq/l
COD Removal Efficiency	49.19%
BOD Removal Efficiency	76.6%

Table 4: Operation and Preformance of Facultative Aerated Lagoon

Parameter	
Capacity	82, 500 cubic meter
Quantity of Influent /Day :	9996 cubic meter
Total BOD load :	4448 Kg. BOD/Day@ 445 mg/l
Total COD load :	234906 Kg COD/Day @ 2350 mg/l
MLSS Concentration :	3260 mg/l
	i.e. 368950 Kg./82500 m^3
MLVSS Concentration:	1795 mg/l
	i.e. 148087.5Kg/ 82500 m^3
Volumetric Loading :	0.04 Kg. BOD/m^3/day
	0.24 Kg. COD/m^3/day
Organic Loading Rate :	0.03 Kg. BOD/Kg. MLVSS
	0.012 Kg. BOD/Kg. MLSS
Retention Time	8.25 Days
F:M Ratio	0.03
COD Removal Efficiency :(Including Secondary clarifier)	71%
BOD Removal Efficiency :	80.2%

Primary Clarifier for Combined Effluent

A primary clarifier with diameter of 38m and side depth of 4.5 m. having a volume of appox. 5100 m^3 has been provided for clarification of balance/ brown water alongwith overflow of UASB reactor. Based on a volume of 9660 m^3/day, the surface loading comes out to be 8.5 m^3/m^2/day which is well within the recommended range of 8-16 m^3/m^2/day. The S.S removal efficiency of the primary clarifier has been calculated to be 56.8%

Facultative Aerated Lagoon

The operation and performance of the facultative aerated lagoon has been summarized in Table 4. The combined effluent clarified in the primary clarified along with the part of black liquor anaerobically in the anamet reactor after clarification in the intermediate clarifier is fed in the facultative aerated lagoon for aerobic treatment of the effluent in ABC Paper. As per data available in the literature, the general operating parameters for aerated lagoon are as follows:

Organic Loading Rate : 0.04-0.15 Kg. BOD/ Kg.MLSS/day

Volumetric Loading Rate : 0.04-0.4 Kg. BOD/ cu. mtr./day

Retention Time : 2-10 days (usually 5/6 days)

MLSS Concentration : 2500-6000 mg/l

In ABC Paper, volumetric load applied on the aerated lagoon is at the minimum limit for such kind of process. Organic loading rate is also far behind i.e. 0.01 Kg. BOD/Kg. MLSS/day in comparison to the maximum permissible limits i.e. 0.04-0.51 kg. BOD/Kg. MLSS/day. It means that at present, the aerated lagoon is working under capacity and if available it can handle more than double of existing volume of combined effluent without affecting the treatment quality of the system. This higher MLSS (Mixed Liquor Suspended Solids) concentration in the aerated lagoon may be attributed to the continuous addition of an Bio-culture by ABC Paper and multiplication of the bacterial population present in the system. The BOD load on the facultative aerated lagoon works out to be 4448 Kg./day, which means that a minimum of 4448Kg. of oxygen is required for the proper aerobic treatment of effluent in the facultative lagoon. In ABC paper, 14 Nos. of 25 HP aerators

Table 5: Overall efficiency of Effluent Treatment Plant

Parameter	Incoming Load/day	Final Load Leaving ETP	% Removal efficiency
Suspended Solids	37883 Kg.	910 Kg.	97.5%
COD	81552 Kg.	6742 Kg.	91.7%
BOD	29823 Kg.	880 Kg.	95.7%

have been provided in the aerated lagoons which are capable of generating 7240 Kg O_2 per day indicating that the oxygen generation capacity of lagoon is sufficient enough for the treatment total volume of 9996 m^3 effluent/day currently being generated.

Secondary Clarifier

A secondary clarifier has been provided to remove the active biomass from the aerobically treated effluent, which is recirculated back in the aerated lagoon to maintain the required MLSS concentration in the system, Surface loading for the secondary clarifier for a volume of 9996 m^3 per day has been calculated to be 8.8 m^3/m^2/day which is also within the recommended range of 8-16 m^3/m^2/day for the clarifiers followed by aerobic system and hence sufficient.

The overall efficiency of the effluent treatment plant has been given in Table 5. the pH, BOD, COD and SS concentration in the final treated effluent in ABC Paper are 7.39, 88 ppm, 675 ppm and 91 respectively.

CONCLUSION

The findings of the above study revealed that a combination of conventional activated sludge process and high rate biomethanation system could treat the paper mill effluent to the limits for the treated effluent on-land irrigation Due to the presence of lignin compounds, some colour always remains in the paper mill effluent, which however, posses no harm to the soil. The level of COD could not be brought down below 650-675 ppm for which further treatments such as lignosulphonate or lignin recovery from the black liquor is required.

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REFERENCES

1. Vuoriranta, P., Rintala, J. and Morange, H. Water-Sci. Technol., 19 (7) 1219-21(1987)

2. Mehner, A., Morange, H., Rintala, J., Silvo, R., Viitasaari, M. and Vuoriranta, P. Water-Sci. Technol., 20 (1) 241-50(1988).

3. Russo, S.L. and Dold, P.L. Water-Sci.Technol., 231 (4-5): 121-32 (1989)

4. Sierra-Alvarez, R., Harbrecht, J., Kortekaas, S. and Lettinga, G. J. Ferment. Bioeng., 70 (2) 119-27 (1990)

5. Rintala, J. A. and Lepisto, S.S. Water-Res., 26 (10)1297-1305 (1992).

6. Kroiss, H., Svardal, K. and Nowak, O. Water-Sci.Technol., 25(1) 23-30 (1992).

7. Rintala, J., Sanz-Martin, J. L. and Lettinga, G. Water-Sci.Technol., 24 (3-4)149-60(1991).

8. Dangcong, P. and Qiting, J. J.Chem. Technol, Biotechnol 58 (1) 89-93 (1993).

9. Repeti, R. The UASB process for the anaerobic treatment of industrial waste with a high organic content. Boll. Chim. Farm., 130(5)157-61 (1991).