Integrated Approach For Water Conservation And Pollution Reduction: A Step Towards Minimum Impact Mill.

Chinnaraj S., Sankaralingam P., Ravi K., & Subrahmanyam S.V.

ABSTRACT

Water conservation measures, such as, use of clarified machine effluent for bagasse washing, replacement of drum washers with press washers, use of cloudy filtrate in high pressure showers after treatment in Algas filter in PM-1, Collection of sealing water in HW fiberline and recycling and Brown stock washing in Bagasse fiberline with evaporator condensate, reduced the water consumption. It was foreseen that the impact of above would have negative effect on the wastewater concentration. To address this, a strategy was framed to eliminate or reduce the high impact wastewater streams which have significant impact on wastewater concentration viz. reduced softener backwash (by replacing soft water with chemically treated process water), recycling of HW E_{OP} filtrate in post Oxygen washer, reduced reuse of final treated effluent, use of pre-thickener filtrate in decker washing of bagasse fiberline, use of debarked *Casurina* and *Subabul* wood and bleach plant process modification and optimization of chemical consumption.

Apart from the above, the mill has following plan in pipeline to further reduce water consumption and pollution load viz. Oxygen delignification & Brown loop closure in Bagasse fiberline, Use of cloudy filtrate in high pressure showers after treatment in Algas filter in PM-2, Increased COD concentration and reduced hydraulic load to improve biogas generation, recycling of extraction filtrate in Bagasse fiberline, Segregation of evaporator condensate based on COD for reuse, process automation for effective process control to optimize the chemical use and pilot trials to treat acidic effluent from bleach plant using membrane process.

Introduction

GDP growth has started tilting towards Asia and emerging nations like India will play important role in world GDP growth in the years ahead. Growing evidence suggests that future growth will create social inequities, environmental degradation, and climate change, if it is unchecked and allowed to grow in old fashion. Especially, for developing nations like India, growth must be coupled with creation of sustainable livelihoods and replenishment of scarce natural resources. By 2050, the world's population will touch 9 billion. The world will have to produce more food, fuel, and fibre resulting reduction in arable land and water availability and about 3 billion people are estimated to live in areas of extreme water scarcity, UNEP, WBCSD (1,2). Per capita paper consumption is only 9.2 kg in India, which is much lower when compared to other neighboring developing economies, such as, China (42 kg) & Indonesia (23 kg). Currently Indian economy is growing by 7.5% per annum. Along with economical growth, the paper demand is also expected to grow and cross 20 million tones per annum by 2020 from current 10 million tones, Pachisia (3).

During 70's, pulp and paper mills water consumption per ton of product was as high as 250m³/adt and today it ranges from 40 to 120 m³/adt depending on the process and technology used by various mills. The higher water consumption is mainly due to the fact that water is still an inexpensive commodity for industry and cost of water is calculated for collecting, treating and distributing. But it is obvious that this situation would change shortly especially in countries like India where we have limited source of water. Other reason for high water consumption is simple: more water a mill uses, cleaner are the pulp and the processes, because water removes most of contaminants and when water systems are closed and water consumption minimized, these contaminants may cause problems as production and final product quality losses, Chinnaraj *et al* (4).

Developments in the beginning of last decade in process technology are focused towards the better environmental performance in pulp and paper industry to address the issues at source to reduce the loss of usable raw or intermediate materials to avoid the need to treat these materials in the end of pipe wastewater or solid waste treatment system Bryant *et al* (5), NCASI, USA (6), CPCB India (7), Gullichsen (8), Johnson *et al* (9) and Pryke (10). This has resulted substantial reduction in the pollution load, energy and water consumption. More recent deployment to close up water circuits towards Zero Liquid Discharge (ZLD) or minimum impact mill in pulp and paper industry to further reduce discharges and water consumption lead to some issues, such as, increased chemical and energy consumption, scaling, process and end product quality variations Bryant *et al* (5) and process upsets in the wastewater treatment process Richard (11,12), Jenkins *et al* (13) and Flippen *et al* (14). Therefore, concept of minimum impact mill raises wide range of challenges covering above issues and need to be worked out taking into account economic aspects and also individual

Tamil Nadu Newsprint and Papers Ltd,
P.O. Kagithapuram-639136
Distt. Karur, Tamil Nadu , INDIA

working environment. For example, in India environmental standards for wastewater discharge and emission are purely on concentration based. Any measure taken by the mill to reduce the water consumption wound results in reduced discharge of wastewater with resultant increase in concentration. In this paper we discuss how an integrated approach was adopted in our mill to reduce the water consumption as well as reduced the pollution load in an economical way.

Results and Discussion

Mill Development Plan:

During middle of 2008, TNPL has successfully completed MDP with a view to achieve more environmentally friendly operational performance of the mill and simultaneously accomplish the objective of modernization of the process technology. The total cost of MDP was Rs. 6120 million. As part of MDP, TNPL has installed a 300 tpd modern hard wood fibre line with Super-batch® cooking, Oxygen delignfication followed by Elemental chlorine free (ECF) bleaching sequence and a 500 tpd ECF chemical bagasse bleach plant to replace the conventional chlorine based bleach plants operated in bagasse fibre line. Though the unit has spent Rs. 6120 million under MDP, the total finished paper production has marginally increased from 205,000 tpa to 245,000 tpa. because, the maximum expenditure was incurred towards the implementation of cleaner technologies keeping with the basic philosophy of improved economy of operation through better environmental management. The specific water consumption per MT of pulp was reduced from by more than 60% i.e. from 73 m^3 per MT of pulp in 2007 to 26 m^3 per MT of pulp in 2011. The details on reduction on water consumption are presented in Figure 1.

Water conservation in PM-1 and PM-3:

Algas filter in Paper machine 1 was installed to reduce the suspended solids (fines and fillers) in cloudy filtrate from about 120 ppm to about 20 ppm. Super clear water has replaced fresh water in high pressure showers in paper machine in the year 2010. This has reduced the fresh water consumption by about 1500m^3/day. Adaptation of improved technologies to acquire super clear filtrate from "Save All" to replace maximum fresh water usage in the newly commissioned third Paper Machine has also reduced the water consumption substantially. The above measures in the paper machine reduced specific water consumption per MT of paper from by more than 30% i.e. from 18.6 m^3 per MT of paper in 2007 to 13 m^3 per MT of paper in month of September 2011. The results are presented in the Figure -2.

Recycling paper machine effluent after clarification: Nearly 9000 m^3 fresh water/treated effluent was used in the bagasse handling and storage area till June 2009. Paper machine wastewater, which contains relatively low TDS, was identified as an alternate to fresh water/treated effluent. It was clarified using one of the clarifiers separately and pumped to bagasse handling and storage area for use. This has reduced average fresh water consumption by 6000 m^3 and also TDS entry to process from treated wastewater.

Recycling of Eop alkaline filtrate to reduce water consumption and energy: Use of alkaline filtrate in PO press instead of discharging into wastewater stream resulted in saving of 1800 m^3 of hot water (80°C) generated from Superbatch® cooking process and it was diverted to CBP ECF bleaching resulting in saving of 0.3 MT of LP steam per tone of pulp that is used for generating LP steam in CBP ECF. About 80m^3/hr of excess hot water is pumped to CBP ECF plant, thereby reducing hot water generation using LP steam. This reduces 0.3 t LP Steam per ton of pulp in bagasse ECF plant accounting annual saving of Rs 20 million. The Environmental benefits of EOP recycling are presented in the Table: 1. The results of impact of Eop recycling on process is presented in Table 2 and it clearly shows no negative impact on the process Bryant *et al* (5) and Ferreira *et al* (15). However, scale formation and deposits were observed to be relatively high in pipe lines and post oxygen press roll perforations affecting the production. This was resolved by adding Antiscalant chemical in EOP filtrate and acid boil out of press roll once in six months. Due to recycling, about 1400-1500 kg of chloride per day is carried over to soda recovery plant. Chloride carryover to SRP is removed by installing decanter

Figure 1: Water Consumption in Pulp Mill

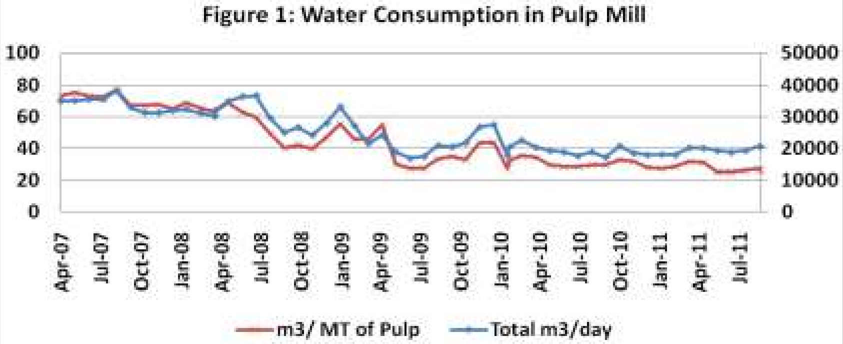


Table 1: Benefits of Eop alkaline filtrate recycling

Reduction water consumption	1400 m^3/Day
Reduction in effluent discharge volume at 80°C	1400 m^3/Day
Colour reduction	1500 Kg/Day
Sodium reduction as Na	2500 Kg/Day
Total dissolved solids reduction	6000 Kg/Day
COD reduction	2800 Kg/Day
AOX reduction	30 Kg/Day
GHG reduction	4.1 MT/day CO_2e

Figure 2: Water Consumption in P/mc

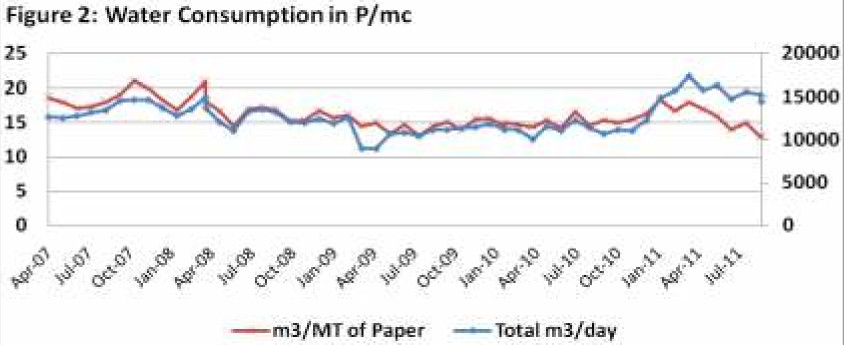


Table 2: Results on impact of Eop alkaline filtrate recycling on the process

Before Recycling				After Recycling			
Month	Alkali Loss as Na_2SO_4	ClO_2 kg/T	Brigt. % ISO	Month	Alkali Loss as Na_2SO_4	ClO_2 kg/T	Brigt. % ISO
Dec-08	11.96	19.7	40.4	Mar-09	14.0	23.12	40.0
Jan-08	13.00	19.6	41.0	Apr-09	12.0	18.90	43.0
Feb-08	14.00	22.5	40.0	May-09	11.8	20.40	42.0

of 30 tpd capacity for ESP ash handling system.

Debarking of Casuarina and Subabul:

Total dissolved solids (TDS) is a major impact parameter for any water conservation measures because the discharge levels prescribed by the regulating authorities are based on the concentration and any measure taken to reduce water consumption will lead to increase in concentration especially the TDS Bryant *et al* (5). Recycling of Eop filtrate and recycling of paper machine waster has helped to a great extent to reduce TDS impact. In the raw material, especially the wood bark account for about 10-20% of the total weight depending on the species and age. Debarked wood is normally used for pulping to reduce detrimental effect affect on pulp quality Dence *et al* (16). Due to shortage and non availability of raw material, wood varieties, such as, *Casuarina, Subabul* are received with bark and 1.5-2.5 year age. In general *Eucalyptus* is debarked at filed and some rare cases even *Eucalyptus* is also brought to mill with bark due to non availability of labour in the field. The bark content and non process elements of *Casuarina* and *Subabul* are presented in Table 3, 4 and 5.

The results in the table 3,4 and 5 indicates that contribution of non process elements concentration is several times higher in bark compared to the woody portion that has significant impact on TDS level in the wastewater. Therefore, debarking was introduced in the mill to improve the process as well as environmental performance.

Implementation of advanced process technologies under Mill Development Plan and Mill Expansion Plan along with in-house process optimization, as stated above, reduced the specific water consumption by 50% i.e. from 102 m^3 per MT of paper in 2007 to 50 m^3 per MT of paper in September 2011 without much impact on the wastewater characteristics especially TDS. Month wise water consumption details are presented in the Figure 3.

Energy from wastewater and pollution reduction:

The High BOD Stream consisting of about 15,000 to 20,000 m^3 of wastewater from Bagasse storage yards and Bagasse preparation plant (Stream A) was treated in closed biomethanation reactor instead of open lagoon to generate biogas and to avoid greenhouse gas emission. The wastewater is clarified in bagasse clarifier. The underflow sludge from the bagasse clarifiers are dewatered through belt press followed by screw press and used as boiler fuel. The overflow from bagasse clarifier overflow is further treated in the Bio-methanation plant to generate bio-gas and to reduce the organic pollution load. The biogas generated from the biomethanation plant is utilized at Lime Kiln as fuel to replace furnace oil. Around 85-90% of reduction in COD and around 95% reduction of BOD is achieved across the bio-methanation plant. This is the first registered Clean Development Project from pulp paper industry and reduces around 45,000 MT of CO_2 equivalents per year and reduced end product specific carbon foot print Chinnaraj *et al* (17). The capacity of the plant was further augmented by additional reactors in 2008. Economic and environmental benefits are presented in the following Table 6.

The low BOD and High volume stream consisting of wastewater from Pulp Mill, Paper Machine and Soda Recovery plants (Stream B) along with Stream A is taken to Clarifier 1 & 2. The suspended solids are removed

Figure 3: Overall Water Consumption

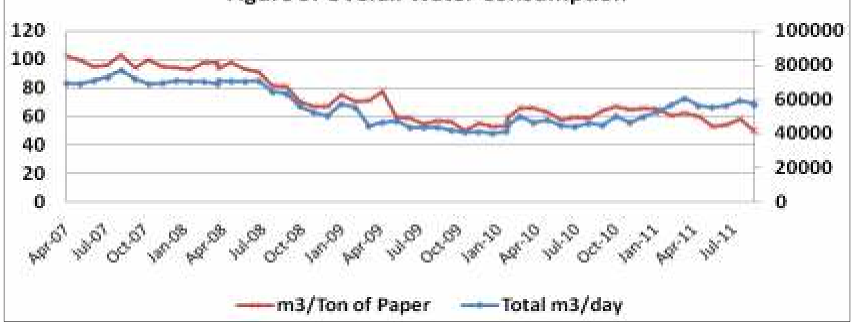


Table 3: Ratio of Bark and wood in *Casuarina*

Wood dia	Moisture %		Proportion % as received		Proportion % on OD basis	
	Wood	Bark	Wood	Bark	Wood	Bark
1" – 2"	41.8	44.8	90.2	9.8	90.7	9.3
2" – 4"	44.4	56.1	91.4	8.6	93.0	7.0
4" – 6"	40.0	50.2	89.2	10.8	90.9	9.1

Table 4: Ratio of Bark and wood in *Subabul*

Wood dia	Moisture %		Proportion % as received		Proportion % on OD basis	
	Wood	Bark	Wood	Bark	Wood	Bark
1" – 2"	33.65	82.20	84.6	15.4	95.3	4.7
2" – 4"	36.64	83.10	89.0	11.0	96.8	3.2
4" – 6"	35.50	77.20	92.7	7.3	97.3	2.7
6" – 8"	38.10	76.10	93.7	6.3	97.5	2.5

Table 5: Non process elements in *Casuarina* and *Subabul* wood and bark

Parameters	*Casuarina*		*Subabul*	
	Wood	Bark	Wood	Bark
Silica %	0.005	0.207	0.011	0.29
Mixed oxides %	0.03	0.16	0.04	0.51
Calcium as Cao %	0.26	1.32	0.40	3.09
Magnesium as MgO %	0.03	0.14	0.09	0.21
Potassium as K %	0.055	0.19	0.09	1.51

Table 6: Economical and environmental benefits from biomethanation plant

Particulars	Units	2009-10	2008-09	2007-08	2006-07
Generation of Biogas per annum	m^3	5797777	4689336	5755200	5162300
Savings of Furnace oil per annum	KL	3479	2814	3453	3097
Emission reduction of GHG per annum due to CH_4 avoidance	MT $CO_{2}e$	65062	52623	64584	57931
Emission reduction of GHG per annum due to Furnace Oil saving	MT $CO_{2}e$	11281	9124	11198	10044
Total Emission reduction of GHG	MT $CO_{2}e$	76342	61747	75782	67975

Table 7: Treated effluent characteristics of TNPL

Parameter	Unit	Norms	TNPL Results
pH		6.5 – 9.0	7.5 – 7.8
BOD5	ppm	30	< 10
COD	ppm	250	160 - 200
Total Suspended Solids	ppm	100	40 - 50
Total Dissolved Solids (in-organics)	ppm	2,100	1,400
Colour, Pt. Co units	ppm	-	200-250
AOX	Kg/T	1.0	0.1

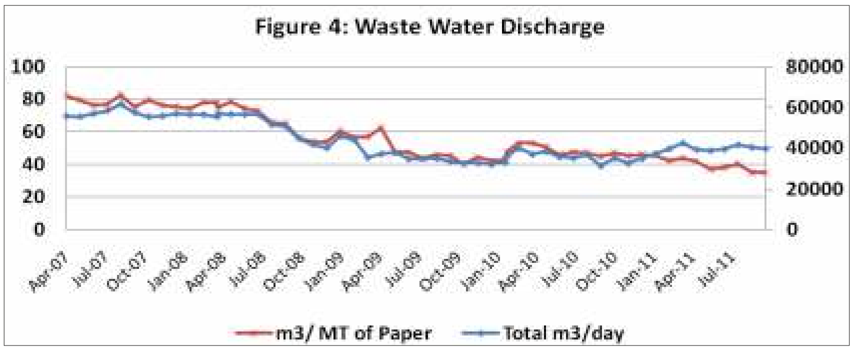


Figure 4: Waste Water Discharge

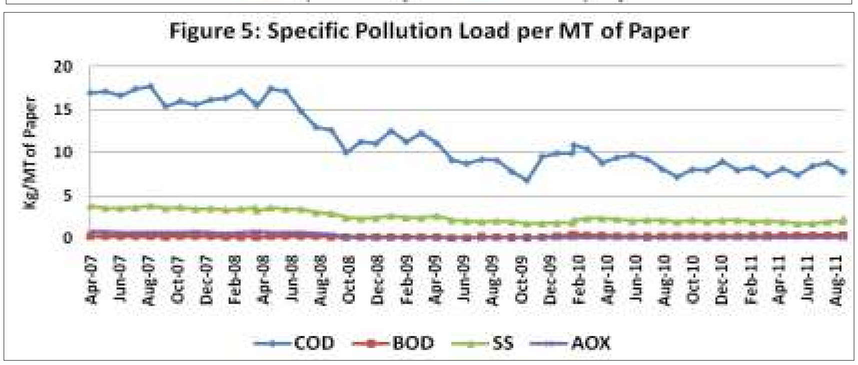


Figure 5: Specific Pollution Load per MT of Paper

through vacuum filter and disposed as raw materials to nearby board mills. The overflow both Streams A & B) are taken to secondary and tertiary treatment viz. Activated sludge process and Ozone treatment. Around 25% treated waste water is recycled for plant use and the balance is being let out as treated effluent from the Mill for on land irrigation to local farmers. The typical parameters of the final treated effluent is as below in the Table 7.

All the above measures reduced specific wastewater discharge per MT of paper by 57 % i.e. from 82 m^3 per MT of paper in 2007 to 35 m^3 per MT of paper in 2011. The COD, BOD SS and AOX discharge per MT of paper has come down by 54.5%, 56% 47% and 87% respectively when compared to 2007. The details on reduction on wastewater discharge and pollution load are presented in following Figure 4 and 5.

HW bleaching process modification: Hard wood wastewater temperature, pH, TDS and sulphate in the wastewater are the major impediment in the biological wastewater as well as membrane treatment processes. High temperature, sulphate and low pH creates filaments forming thereby bulking, which affects the sludge settling leading to higher suspended solids carryover in secondary clarifier and also to certain extend increases corrosion Richard (11,12), Jenkins *et al* (13) and Flippen *et al* (14). Cooling towers were installed to reduce the temperature of the wastewater. To reduce TDS, sulphate and improve pH, bleaching process was modified by stopping the sulpuric acid addition before D_{HT} stage and trails were taken at plant scale. The impact of bleaching process modification on wastewater characteristics, such as, Colour, Total solids, Total dissolved solids, Total suspended solids, Total dissolved solids (in-organic), Chemical oxygen demand (COD), Sodium, Potassium, Total Hardness, Calcium Hardness, Magnesium Hardness, Chloride, Conductivity and Sulphate as SO_4 are presented in Figure -7 (D_{HT} filtrate) and Figure - 8 (Eop filterate). The Figure -7 indicates that there is reduction in all above parameters of wastewater except colour, COD and Chlorides. High reported colour is mainly due to increase in pH from 2.6 to 5.8. High COD and Chlorides are mainly due to increase in through put and chlorine di oxide consumption during the trail when compared to earlier. Figure 8 indicates that there is increase in all parameters in Eop filtrate except sulphate. But it will not have much impact in the downstream treatment, because, majority of Eop filtrate is recycled back in to the system and not let in to the wastewater. In addition to the environmental benefits, notable amount of chemical savings are also observed especially Sodium

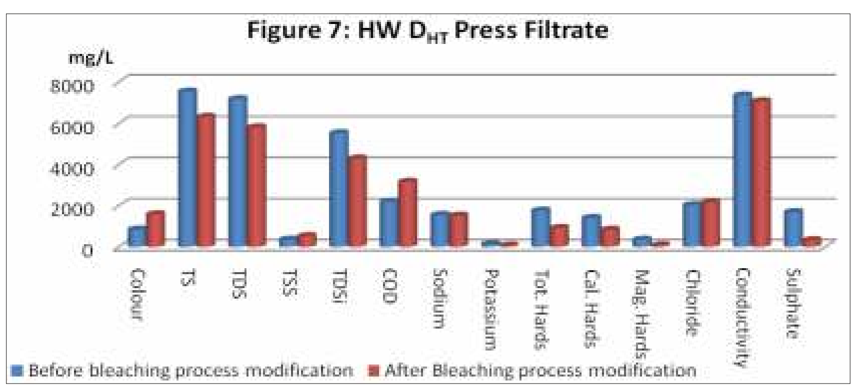


Figure 7: HW D_{HT} Press Filtrate

hydroxide, Oxygen, Sulphuric acid and sulphur di oxide and marginal increase of ClO_2 and hydrogen per oxide H_2SO_4 (Table 8). There was no notable change in final pulp strength and optical properties. Chemical saving would definitely improve the economic and operational performance of the fibreline.

ZLD pilot plant study:

TNPL have an ambitious program to implement ZLD for acid effluent from the bleach plant. It targets at treating the acidic bleach filtrate using physico-chemical pretreatment followed by membrane separation and recovering 85% of water. The sludge generated in this operation will enter appropriate stage in lime sludge cycle and concentrate organic matter (membrane process rejects) will be sent to chemical recovery and dilute brine water will be concentrated to marketable level to use as input to chloro-alkali plant elsewhere. The pilot at the cost of RS 40 million is commissioned in the month of October 2011. The Schematic process flow sheet is presented below in the Figure 6.

Proposed water conservation projects: 1. Reuse of Cloudy Clear filtrate in PM-2 showers after filtration with Algas system, 2.Oxygen delignification & Brown loop closure in Bagasse fiberline, 3. Recycling of extraction filtrate in Bagasse fiberline and 4. Segregation of evaporator condensate based on COD and reuse. 5. Increased COD concentration and reduced hydraulic load to improve biogas generation and 6. Process automation for effective process control to optimize the chemical use.

CONCLUSIONS

In TNPL by applying both conventional and new advanced process technology and also through in-house research, we are able to reduce specific flesh water consumption by 50% and waste water discharge by 57% and improve the environmental performance viz. COD, BOD SS and AOX discharge 54.5%, 56% 47% and 87% respectively when compared to 2007. But there are many limiting factors like TDS inorganic which restricts the reuse of wastewater, closure of water circuits and further reduction of fresh water consumption. Closing of water circuits tightly with current technology can create many operational problems like concentration buildup of non-process elements and scaling in process streams and reduced product quality etc. Non-process elements enter the process through raw materials and sometimes even through fresh water. This needs economically viable technology to purge water circuit contaminants in case water use in the paper industry is to be significantly reduced further, especially for the acidic bleach plant effluents and from ESP ash from recovery boilers. As indicated earlier, TNPL has taken up this issue and put up an ambitious program to implement ZLD pilot plant ($5m^3$/hour) for acid effluent from the bleach plant. It targets at treating the acidic bleach filtrate using physico-chemical pretreatment followed by membrane separation and recovering 85% of water. The sludge generated in this operation will enter appropriate stage in lime sludge cycle and concentrate organic matter (membrane process rejects) will be sent to chemical recovery and dilute brine water will be concentrated to marketable level to use as input to chloro-alkali plants elsewhere. The plant was commissioned in the month of October 2011. Let us look for positive results.

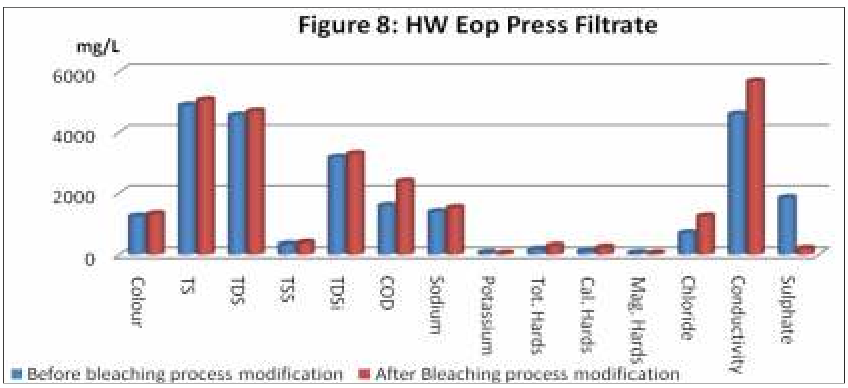
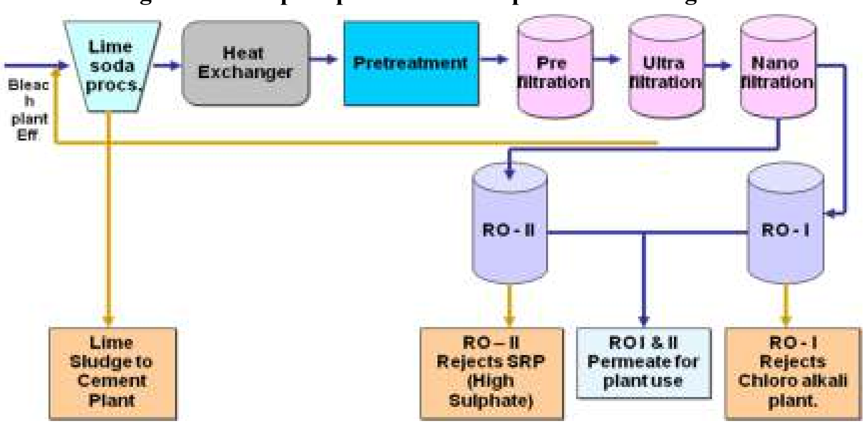


Figure 8: HW Eop Press Filtrate

Table 8: Chemical consumption before and after bleach process modification

Name of the chemical	Units	Before bleaching process modification	After Bleaching process modification
Sodium Hydroxide	kg/t	40.0	32.6
Oxygen	kg/t	28.8	25.1
Chlorine Di Oxide	kg/t	19.2	20.0
Hydrogen Per Oxide	kg/t	15.3	18.9
Sulphuric Acid	kg/t	19.7	Nil
Sulphur di Oxide	kg/t	2.23	Nil

Figure 6: ZLD pilot plant schematic process flow diagram



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REFERENCES:

1. UNEP: Vital Water Graphics: An Overview of the State of the World's Fresh and Marine Waters - 2nd Edition, United Nations Environment Programme (UNEP) | P.O. Box 30552 | Nairobi, Kenya (2008).
2. WBCSD: Business in the world of water (2007). Water Scenarios to 2025. The World Business Council for Sustainable Development. 4, chemin de Conches, CH-1231

Conches-Geneva, Switzerland, www.wbcsd.org

3. Pachisia M. L. Presidential address Indian Paper Manufactures Association, XI[th] Annual General Meeting, 7[th] January 2011 Hotel Le Meridien, New Delhi, (2011).
4. Chinnaraj S., K. S. Rajesh, P. Karunanithi , N. Baskaran and S.V. Subrahmanyam. IPPTA, **22(1):** 151-156, (2010).
5. Bryant P.S., Malcolm E.W and C.P. Woitkovich (1996). Pulp and Paper Mill Water Use in North America IP*ST Technical* P*aper* S*eries Number 601* TAPPI *E*nvironmental Conference Orlando, Florida USA
6. NCASI (2009). Water use performance and practices at low water use mills. Environmental foot print comparison Tool. National Council for Air and Stream Improvement, Inc.. Technical Bulletin No. 968. Research Triangle Park, NC USA.
7. CPCB (2006). Final report on development of guidelines of water conservation in pulp and paper sector. Submitted by: Environment Group National Productivity Council , New Delhi.
8. Gullichsen J. (1991). Process internal measures to reduce pulp mill pollution load. Water Science and Technology: 24(3 & 4): 45-53
9. Johnston P.A., R. L Stringer, D. Santillo, A. A. Stepahenson, I.P. Labounskaia, and H. M.A. McCartney (1996). Towards zero effluent pulp and paper production: The Pivotal role of totally chlorine free bleaching, Greenpeace International, Amsterdam, Technical Report 7/96
10. Pryke D.C., Winter P, Bouree G.R. and C. Mickowski (1998). Elemental chlorine free bleaching, Anthology of published papers (Edited by Katherine A. Kulas), Tappi Press, Atlanta, USA.
11. Richard M. (2003). Activated sludge microbiology problems and their control, Presented at the 20[th] Annual USEPA National Operator Trainers Conference, Buffalo, NY, USA.
12. Richard M. (1997). Recent Changes in the Prevalence and Causes of Bulking Filamentous Bacteria in Pulp and Paper Mill Activated Sludge Systems. proceedings of the 1997 TAPPI Environmental Conference, p. 553, Minneapolis- Saint Paul, MN. USA.
13. Jenkins, D., M.G. Richard and G.T. Daigger (1993) Manual on the Causes and Control of Activated Sludge Bulking and Foaming, 2[nd] Ed., Lewis Publishers, Boca Raton, FL, USA
14. Flippen, T.H. and W.W. Eckenfelder, (1994). Effect of Elevated Temperature on the Activated Sludge Process. Proceedings of the 1994 TAPPI Environmental Conference, p. 947, Portland, OR. USA.
15. Ferreira G. A. L., Soares, M.A.R. Egas A.P. and J. A. M. Castro J (2003). Selective removal of chlorine and potassium in kraft pulp mills. *Tappi Journal:*2 (4): 21 25.
16. Dence C.W . and C.W.D. Reeve (1996). Pulp bleaching Principles and Practice*,* Tappi Press, Atlanta, USA, Page 756
17. Chinnaraj S., Vijayakumar T. Kumar M. Senthil and S.V. Subrahmanyam. IPPTA, **23(1):** 147-150. (2011).