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Techno-Economic Sustainable Option Adopting Zero Liquid Discharge in Wastepaper Based Pulp & Paper Industries

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ABSTRACT

In Indian practices paper manufacturing is a highly capital, energy and water intensive industry. The high water consumption is mainly due to obsolete process technology, quality of end product, poor water management practices and inadequate wastewater treatment. The performance efficiency of Effluent Treatment Plant (ETP) in small to medium scale waste paper based industries is very poor mainly due to lack of process optimization, poor fiber recovery, low performance of pulp washing systems, inadequate specifications of ETP units in terms of volume of wastewater & pollution load to be handled, and low priority to efficient ETP operation to save power & chemical consumption. In recent past, considerable efforts have been made by the Recycled Fiber (RCF) based Pulp & Paper industries to reduce pollution loads and fresh water consumption through process optimization for efficient water usage, better housekeeping and increased reuse of back water. The possible option is Close-up of all water loops from process by total recycling inside a process sequence or into a different process sequence within the industry namely ZLD. Completely closed water loops meaning that there is no wastewater produced at all and fresh water (as make-up water) therefore is only fed at the same volume rate as it is removed by evaporation in the dryer section of the paper machine and with the rejects leaving the industry.

KEYWORDS

Effluent Treatment Plant (ETP), Recycled Fiber (RCF), Zero Liquid Discharge (ZLD).

INTRODUCTION

Paper manufacturing is considered as one of the highly polluting industry, requires substantial investments in pollution control equipment. At the beginning of the 20th century, about 500 to 1000 m^3 of water was required for the production of one tonne of paper[4]. The high water consumption in mainly due to obsolete process technology, quality of end product, poor water management practices and inadequate wastewater treatment.

Since last decade, due to increasing environmental awareness and pressure there has been significant reduction in water consumption and pollution loads in waste paper based pulp & paper industries through the increasing closure of the in-house water circuits[7].

In recent past, considerable efforts have been made by the industries to reduce water consumption by estimating water requirement, quality of water required in different processes and based on values estimated as well as best achieved[12]. Close-up all process water loops by total recycling of generated effluent, inside a process sequence or into a different process sequence within the industry has been identified as a techno-economically sustainable option to achieve Zero Liquid Discharge (ZLD)[6].

POLLUTION SOURCES IN PAPER INDUSTRY

The most significant sources of pollution among various process stages are raw materials preparation, pulping, pulp washing, screening, washing, and paper machine and coating operations[10]. The effluents from the pulp and paper industry cause slime growth, thermal impacts, scum formation and loss of aesthetic beauty in the

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environment. They also increase the amount of toxic substances in the water, causing death to the zooplankton and fish, as well as profoundly affecting the terrestrial ecosystem[5]. The main sources of pollution in paper industry is from raw material preparation, pulp washing and paper making.

CHARACTERIZATION OF UNTREATED WASTEWATER

The pollution in the wastewater of a paper mill depends on the type of raw material, the quality of recycled paper and amount of fillers and chemical additives applied and on the degree of circuit closure. The use of starch or other organic additives results in a marked increase in BODs or COD. Dyes and fillers can lead to discoloration and/or turbidity of effluents. The closure of the water circuit within the mill results in an increase in the concentration of the effluent components[9]. On the other hand, the inorganic and organic load is reduced owing to its partial elimination via the paper produced. For this reason, the specific load in kg per tonne of paper (specific load = concentration x specific amount of effluent) is a more suitable parameter for quantifying the effluent pollution.

PROCESS WATER OR RECYCLED WATER

The majority of water used in a paper mill is process water or recycled in the different water loops of the water circuit of the system before disposal. The process water is 'produced' in the thickening and dewatering stages of the papermaking process[8]. Due to its content of solid, colloidal and dissolved substances, the quality of the process water is lower than that of fresh water.

CONTAMINANT IN PROCESS WATER AND ITS EFFECT ON QUALITY OF PAPER

Major process changes in paper production in the last two decades are as under:

- Increased use of waste/ recovered paper due to shortage of fibrous raw material
- Shifting from acidic (alum-rosin) sizing system to neutral/alkaline (AKD/ASA)sizing system
- Reduction in fresh water consumption and augment use of recycled water wherever, it is possible after treatment.

DETRIMENTAL SUBSTANCES FROM DIFFERENT SOURCES

Detrimental substances (anionic oligomers and poly electrolytes as well as nonionic hydro colloids) are known as anionic trash and are measured as cationic demand by polyelectrolyte titration in a streaming current device or as chemical oxygen demand (COD).

- **Broke and recovered paper:** coating binders, glues and adhesives,
- **Additives:** fatty acids or silicates, starch and others.

Other sources of anionic trash in fresh water are shown in table 1.

Table 1: Other sources of anionic trash in fresh water

Chemicals	Sources
Sodium silicate	deinking, recovered paper
Polyphosphate	Filler dispersing agent
Polyacrylate	Filler dispersing agent
Starch	Coated broke, recovered paper
Fatty acids	Mechanical pulp, deinking

A lot of problems are caused by these detrimental substances[6] throughout the whole paper-making process such as:

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- Reduction in efficiency of additives,
- Reduction in optical properties like brightness and increased stickiness and dirt content.
- Reduction in mechanical strength properties
- Poor sizing (alum-rosin sizing) but not in case of neutral/alkaline sizing. However, it can be mitigated by reverse sizing in case of acid sizing i.e. use of paper makers' alum first.
- Bad odour due to microbiological activities i.e slime formation and it can be mitigated by proper use of biocides and by proper aeration in water loop.
- Negative effects on drainage and drying: It can be minimized by use of drainage aid
- Reduced paper machine speed due to shower plugging.
- Deposits and foam generation causing defects in paper as well as resulting in paper web breaks.
- Inorganic dissolved substances i.e. salts, are measured as increased conductivity.
- Salts (Inorganic) are also detrimental to the process performance and potentially for the paper properties.
- Electrolytes reduce the swelling potential of fibers.

For different applications, such as sprays in the paper machine, solids (mainly fibers, fines and fillers) in the process water are also disturbing and have to be removed before the water is used.

Table 2: Present limits of system closure

System Application	Specific effluent volume, L/ kg paper	Disturbing effects limiting further closure
Graphic paper grades several water loops counter current flow circuit water cleaning (kidney)	8-10	Decreasing product quality felt shower plugging lower particle retention scaling slime
Board and paper packaging grades	3-5	Odor problems (water and product)
Single or two loops		Corrosion
water treatment only for showers		Deposits

STATE OF ART OF WASTE PAPER BASED PULP & PAPER MILLS - ZLD TECHNOLOGICAL OPTION

The main objective of the ZLD is water loop system are to offer the required volume and quality of water for each consumer and to treat and/or bleed out water containing detrimental substances. Completely closed water loops[9] meaning that there is no wastewater produced at all and fresh water (as make-up water) therefore is only fed at the same volume as it is removed by evaporation in the dryer section of the paper machine and with the rejects leaving the industry.

Detail study comprises of:

Preliminary survey of the selected mills and collection of background data from selected pulp & paper industries regarding the raw material consumption, quality of output product, installed and operating capacity of existing process and utilities through questionnaire, identification of the sources and characterization of the wastewater generated from each process operation, Compilation of material & water balance for complete process, Quantification of the fresh water consumption and wastewater generation being recycled/reused options, if any adopted by the pulp & paper industry.

Two possible options which have been explored to achieve ZLD are:

A. Close up all process water loops by total recycling inside a process sequence or into a different process sequence within the mill.

The objectives of the water loop systems are to offer the required volume rate and quality of water for each consumer and to treat and/or bleed out water containing detrimental

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substances. Completely closed water loops[2] meaning that there is no waste water produced at all and fresh water (as make-up water) therefore is only fed at the same volume rate as it is removed by evaporation in the dryer section of the paper machine and with the rejects leaving the mill[11].

B. Treat the effluent in a stand-alone facility to render it suitable for process, reuse & volume reduction.

In order to recycle the wastewater completely back to the system, wastewater requires undergoing a number of treatment processes to achieve nearly inlet water quality. In a pulp and paper mill, colour removal is an important requirement to use the finally treated wastewater as process water.

An ideal stand-alone facility would require conventional wastewater treatment (primary, secondary and tertiary)[3] to reduce the suspended solids and organic loads, followed by a quaternary treatment (typically, multi-stage reverse osmosis (RO) sequences) to maximize recovery of reusable process water and reduce the volumes requiring subsequent treatment such as evaporation, crystallization and environmentally acceptable management and/or disposal of solids.

Reducing the effluent volumes to zero means that fresh water consumption is reduces to approx. 1.5 Lit/kg of paper, however, this may rise high amounts of detrimental substances. The only solution, to remove the detrimental substances from the process with suitable highly efficient kidney technologies for COD reduction. These include, in addition to circuit water cleaning by coagulation and flocculation with subsequent removal in a dissolved air floatation unit, anaerobic/aerobic combinations of biological treatment, and different membrane filtration technologies like micro-ultra- or nano-filtration[1] down to reverse osmosis or evaporation.

A typical suggested flow diagram of ideal standalone effluent treatment facility could be as under:

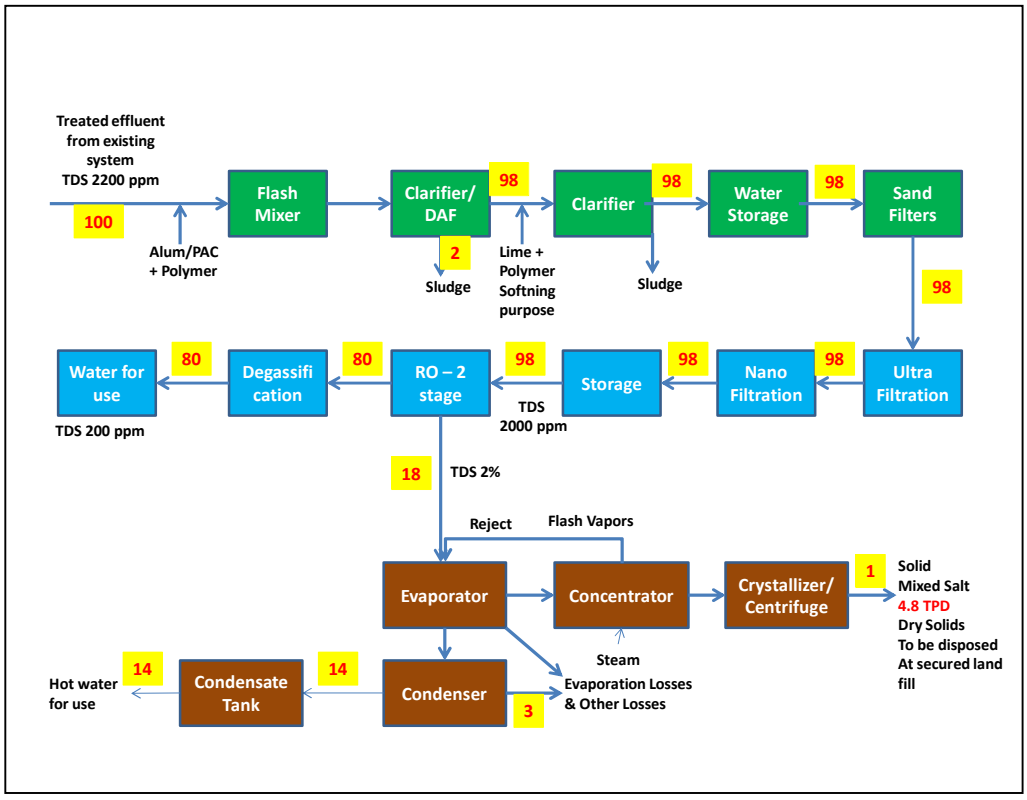

Figure 1: ZLD Concept for Pulp & Paper mills – Suggested Process Flow (Made on Mass Balance)

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Estimated Cost for 100 m3/hr treated effluent is shown below:

Particulars	UoM	Value
Effluent Volume	m^3/hr	100
RO Treatment output	m^3/hr	80
RO Reject feed for evaporation & crystallization	m^3/hr	20
Capital Cost		
RO Plant for 100 m3/hr capacity	Rs.Cr	5.0
Evaporator, Crystallizer & Centrifuge	Rs.Cr	19.0
Civil work pipelines etc.	Rs.Cr	1.0
Total Cost	Rs.Cr	25.0

Investment & Operating Costs is as under:

Particulars	Units	Case 1
Mill Capacity	TPD	100
Effluent Volume	M^3/day	4000
Capital cost for RO & Evaporation	Rs.Cr.	45
Power Requirement for ZLD	MWH	1.0
Capital cost for Power Plant	Rs.Cr.	4.0
Total Capital Cost	Rs.Cr.	49
Operating Cost (@127 Rs/M3)	Rs/Mt paper	5000
Interest Cost (@10%)	Rs/Mt paper	1342
Total Operating Cost	Rs/Mt paper	6342
Annual Operating Cost	Rs.Cr.	23.0

The investment and operative cost based on the suggested flow sheet, for 100 MT per day capacity paper mill has been estimated as above.

CASE STUDIES FOR WATER CONSUMPTION AND WASTE WATER DISCHARGE BENCHMARKING

In recent times some recycled fiber based mills have claimed to achieve zero discharge or near zero discharge status. Two mills in Vapi, Gujarat namely **Vaibhav Paper Boards Pvt. Ltd., & Craft Corner Paper Mills Ltd.,** were visited to study the strategies adopted by these mills which are discussed as under:

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CASE STUDY 1: VAIBHAV PAPER BOARDS PVT. LTD., VAPI GUJARAT

The mill is producing 65 TPD kraft paper and claims to have achieved zero discharge status since last six years. Water balance is achieved in the mill by controlling fresh water addition to the extent of evaporation related to production (drying operation). Circulation of water is totally modified to have following short & closed loop:

- **Pulper → Thickener → Pulper**
- **Centrifugal cleaning system → Wire part → Centrifugal cleaning system**

The reuse and recycling of back water has predictably resulted in increase in concentration of total solids/ dissolved solids, temperature of recycling effluent in the range 48 – 52 ^{0}C but no effect on pulp & paper quality or process operation. The increase in temperature has prevented slime formation/ microbial growth. Interestingly, foam generation is reduced and machine runability has improved. The unexpected results may be attributed to the use of coagulant, flocculant and other formation aid chemical which helps in purging out of all non-process elements and fines with the paper. As a result, no build up takes place in the recirculated water. It has been observed during the visit that mill was odour free indicating that due to short looping and high temperature microbes do not flourish in the systems. A brief account of the mill & its water balance of the mill are indicated in tabular form as under:

A brief Summary of Vaibhav Paper Mill

S.No.	Particulars	Details
1.	Raw Material Used	Waste Paper
2.	End Product	Kraft Paper
3.	Production , TPD	65
4.	No. of Paper Machine	1
5.	Paper Machine Speed , meters per minute	150
6.	Fresh Water Consumption , m^3 / day	85
7.	Volume of Waste Water Discharged	Zero Discharge
8.	ETP	Not Available
9.	Water Holding Tank	Not Available
10.	Areas of Fresh Water Usage	⁾ Gland cooling in refiner ⁾ Chemical preparation (coagulant, flocculant , rosin , bentonite) ⁾ Cutting edge showers on wire part of paper machine
11.	Measures Adopted for Zero Discharge	⁾ Segregation , collection of back water for cascade ⁾ Use of coagulant and flocculant for precipitation of suspended matter , fines etc present in paper machine back water for subsequent purging out with finished paper product ⁾ Maintaining short and closed loop system to avoid retention of back water ⁾ Maintaining continuous circulation of back water to

		avoid microbial growth J Closed circulation results in increase of temperature of back water to around 48-50 °C which helps in arresting the growth of microbial population in back water J Regular monitoring of back water for microbial growth using microbial growth test kit J Blocking of fresh water pipeline to avoid the use of fresh water by workers unnecessary
12.	Additional Remarks	J During the visit to the mill no odor was observed which indicates that due to short looping and high temperature. microbial growth does not take place in the system J The mill claims to be operating it zero discharge system for last six years and has experienced no problem related to quality or production of paper J Mill is also in process of obtaining zero discharge certificate from the authority maintaining common ETP in Vapi

Characteristic of Recycled Water & its Reuse in Vaibhav Paper Mill

S. No.	**Source and Characteristics of Recycle Water**	**Usage Point**
1	**Water in Holding Tank (Collection Tank)**	
	pH 6.0 Colour Pt. Co. Sc. 400 TDS 48520 mg/lit. TSS 2680 mg/lit. COD 32120 mg/lit. BOD 9383 mg/lit.	Used in pulper
2	**Decker Thickener Filtrate Tank**	
	pH 6.0 TDS 48520 mg/lit. TSS 2680 mg/lit.	Used in decker thickener shower, H. D. cleaner, Turbo separator, centri cleaner's reject pit dilution**.**
3	**Wire Pit Silo**	
	pH 5.5 TSS 1200 ppm	Used in centricleaner through fan pump.
4	**Vacuum Seal Pit No. 1**	
	pH 5.5 TSS 1400 ppm	Used in vacuum pump sealing.
5	**Vacuum Seal Pit No. 2**	
	pH 5.5 TSS 1000 ppm	Used in knockdown shower a drilled hole shower pipes 1.0 mm hole.
Holding water tank collects water from excess water at all the points, press part drainage and vacuum pump drainage i.e. sealing water and hosing of backwater in *plants*.		

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Water Balance in Vaibhav Paper Mill

Input			Output		Remarks
Process Operation	**Water Usage**	**Qty m^3 /day**	**Process Operation**	**Qty m^3 /day**	
Pulper	Recycled Water	2529	Thickener	1300	Recycled
Refiner	Fresh Water	9.00			
Mixing Chest	Fresh Water	56.50			
Centricleaners	Recycled Water	5190	Centricleaners	29	Recycled
Wire part of Paper Machine	Fresh Water	20	Wire part of Paper Machine	6305	Recycled
Waste Paper	Moisture	6.5	Press Part	86	Recycled
			Dryer part	87	Recycled
			In Paper	4.00	Moisture goes with paper
	Total	7811	Total	7811	

CASE STUDY 2: CRAFT CORNER PAPER MILLS LTD., VAPI GUJARAT

The mill is producing 60 TPD high qualities Kraft paper. The mill is not discharging any water out of the plant and is achieved the art facilities for water conservation practices. The mill is using self cleaning shower for clothing and has adopted exhaustive anaerobic & aerobic Effluent Treatment Facilities for making the waste water suitable for reuse. The mill has also installed electro-magnetic descaling unit in pipeline of primary clarifier outlet pipeline which is taken into the process. The mill is regularly using biodegradable biocides to prevent microbial and fungal growth in process water. A brief account of the mill & its water balance of the mill are indicated in tabular form as under:

A brief Summary of Craft Corner Paper Mill

S.No.	Particulars	Details
1.	Raw Material Used	Waste paper
2.	End Product	Kraft paper
3.	Production , TPD	60
4.	No. of Paper Machine	1
5.	Paper Machine Speed , meters per minute	210
6.	Volume of Waste Water Discharged	Zero discharge
7.	Areas of Fresh Water Usage	⁾ Cutting edge showers on wire part of paper machine ⁾ High pressure shower on wire part (Once a day)

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		⁃ High pressure shower in press section (once in two days) ⁃ Chemical preparation (rosin , retention aid, gum etc)
8.	ETP	Primary clarifier + anaerobic reactor + activated sludge process
9.	Areas of Reuse of Process Water	⁃ Wire part shower ⁃ Press section ⁃ Vacuum pump sealing ⁃ Thickener decker shower
10.	Measures adopted for Zero discharge	⁃ Regular water audit ⁃ All shower are self cleaning shower ⁃ Exhaustive anaerobic & aerobic effluent treatment facilities for making the waste water suitable for reuse ⁃ Installation of electro -magnetic descaling Unit in pipeline of primary clarifier outlet pipeline which is taken into the process ⁃ Use of biodegradable biocides to prevent microbial and fungal growth in process water ⁃ Recycled process water reused in Wire part shower , press section , vacuum pump sealing and thickener decker shower

FINDINGS FROM THE CASE STUDIES

The experience from selected pulp and paper mills clearly shows that zero liquid discharge is techno-economical options in the waste paper based pulp and paper industries respectively. However, there is a need to set clear goals in terms of water consumption per tonne of the product as well as motivate the small and medium scale pulp and paper industries located in the study areas to adopt cleaner production options.

CONCLUSION

Discharge of the trade effluent is the major point source of pollution. The prevention and control of discharge of pollutants in the river channels needs to be stopped. The proposed approach relies on a two tier action plan:

⁃ Tier I includes water use reduction through process improvements and implementation of the close loop recycle of water.

⁃ Tier II involves quantum improvement on the individual ETPs in terms of adding tertiary treatment units and achieving industry grade water.

By adopting closed loop of ZLD, the wastepaper based Kraft pulp & paper industries will reduce its fresh water consumption to >1.5 m^3/tonne of paper.

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