PROJECT REPORT

Development of Protocol for Evaluating the Feasibility of Zero Liquid Discharge in RCF Based Pulp & Paper Mills

Project Sponsored by Research Steering Committee of Development Council for Pulp, Paper and Allied Industries

Prepared By

Central Pulp & Paper Research Institute

Saharanpur -247001 (U.P.)

February 2023

PROJECT REPORT

Development of Protocol for Evaluating the Feasibility of Zero Liquid Discharge in RCF Based Pulp & Paper Mills

Project Sponsored by Research Steering Committee of Development Council for Pulp, Paper and Allied Industries

Prepared By

Central Pulp & Paper Research Institute

Saharanpur -247001 (U.P.)

February 2023

Project Team

• *Dr M.K. Gupta, Director*	*Technical Guidance*
• *Dr Shivaker Mishra , Scientist E-II & Head Audit Cell*	*Mill Visits & Technical Support*
• *Dr Nitin Endlay , Scientist E-II & Head Environmental Management Div*	*Project Conceptualization , Planning, Mill Visits, Data Compilation Interpretation and Report Preparation*
• *Mr. Mohd Salim , Scientist B , Environmental Management Div*	*Literature Survey, Mill Visits, Analysis & Data Compilation*
• *Mr. Abhishek Tyagi , JRF , Environmental Management Div* • *Mr . Amitabh Tripathi, Technical Executive Environmental Management Div* • *Mr. Deepak Sharma , Technical Executive Environmental Management Div*	*Lab Analysis*

Contents

ACKNOWLEDGEMENT

CPPRI acknowledge with thanks the Hon'ble Chairman & members of Development Council for Pulp , Paper & Allied Industries (DCPPAI) and Research Steering Committee of Development Council for Pulp , Paper & Allied Industries (RSC-DCPPAI) for awarding this project .

Thanks are also accorded to Hon'ble Chairman & members of Technical Sub-committee of RSC-DCPPAI for reviewing the project progress periodically and their valuable inputs.

Thanks are extended to all the pulp & paper mills which extended cooperation to CPPRI Team in carrying out the mill studies under the project.

Central Pollution Control Board , Delhi & State Pollution Control Board of Uttar Pradesh & Uttarakhand are also acknowledged for participating in the valuable discussions on ZLD.

CPPRI also thank Paques India & UNIDO for collaborating with CPPRI to study tecxhnological interventions to mitigate odor issue in pulp and paper mills operating on ZLD through for study on Biomethanation and Chlorine dioxide treatment of back water respectively.

The literature / journals referred in preparation of project proposal , execution of project and report preparation is also sincerely acknowledged

List of Tables

List of Figures

Executive Summary

Executive Summary

This report on RSC-DCPPAI Funded Project **Development of Protocol for Evaluating the Feasibility of Zero Liquid Discharge in RCF Based Pulp & Paper Mills comprises of 6 Chapters**

Chapter 1 covers Background, Objective & Methodology involved in execution of the Project. The project was formulated in the perspective of need by regulatory authorities to develop a protocol so as to validate / verify the feasibility **of Zero Liquid Discharge (ZLD)** status as claimed by RCF based Kraft Paper Mills in various parts of the country . This project aimed at developing a systematic / methodical protocol to validate the ZLD status of RCF based Kraft Paper mills operating on ZLD. A systematic and methodical work plan was formulated to achieve the objective of the project as under:

- Identification and selection of RCF based Kraft , Newsprint paper and Writing & Printing Mill
- Preparation of questionnaire for collection of secondary data
- Preliminary visit for study of process, data collection and identification of sources for sample collection , raw material & end product collection.
- Monthly / bi – monthly visit to each mill for back water sample collection
- Analysis of sample collected for various pollutional parameters , pH , TDS , COD , BOD, Turbidity, Charge & Conductivity
- Lab scale study / evaluation of build up of COD, BOD , TDS etc using mill pulping conditions
- Water & Material Balance Studies
- Study on impact of ZLD vis a vis product quality (due to accumulation of contaminants like slime , stickies , anionic trash) on paper properties and process operations their remediation / control.
- Evaluation of options for reduction in odor related issues in paper and environment due ZLD . (Biomethnation and Chlorine dioxide treatment)

Chapter 2 gives a brief introduction about the Indian Paper industry and RCF based Pulp & Paper Mills particularly the process operation employed and effluent treatment system employed by these mills

Chapter 3 discuss the concept of **Zero Liquid Discharge** in context of RCF based Kraft Pulp & Paper Mills covering **Historical Perspective, Benefits of ZLD , Challenges of ZLD, Major Drivers for ZLD etc**

Chapter 4 includes case studies taken up to develop protocol to validate the ZLD status of Pulp & Paper Mills. The category of mills studied under the project include:

1. **Mill A (RCF Based Produced Bleached Grade (Writing & Printing) Grade Paper**
2. **Mill B (RCF Based Mill Producing Newsprint Grade of Paper)**
3. **Mill C (RCF Based Mill Producing Kraft Paper)**

As indicated in the studies periodical sampling of backwater was carried out in the selected mills to monitor the buildup of TDS . .COD & BOD generation/build up in back water simulating the existing mill conditions From the that the studies conducted it could be safely presumed that the addition of TDS, COD and BOD in back water of RCF based kraft paper mill operation on ZLD per day equals to their loss due to carryover with finished paper & solid rejects .

Chapter 5 with reported cases of foul odor in atmosphere and paper products in mills operating on ZLD the Chapter highlights studies carried out on technological intervention like introduction of biomethanation in back water loop and chlorine dioxide treatment of back water to mitigate the odors issue

Chapter 6 sums up the following conclusions related to the protocol for evaluating feasibility / status of ZLD in a RCF based kraft paper mill which are based on the studies conducted under the project :

- ❑ Fresh Water Consumption benchmark for a mill operating on ZLD is :
- < 2.5 m^3 / t paper for kraft paper mills & newsprint paper mill without cogeneration power plant

- < 5 m^3 / t paper for kraft paper mills with cogeneration power boiler including cooling tower

- Removal of suspended solids through primary clarification / Sedicell is must for checking build up and microbial growth development in water circuit.

- Without ETP or appropriate treatment the mills have to compromise with strength properties of finished product, wire & felt life, machine down time, Odor problem in finish product etc. which needs to be critically documented.

- Critical monitoring of TDS , COD , BOD build up is necessary to check the impact on process operations and product quality.

- In such cases addition of imported waste paper furnish can help in improving / maintaining product quality

- Further studies are required with incorporation of advanced technologies with minimum impact of ZLD on machine productivity and product quality

- Based on the studies conducted , the average TDS , COD & BOD level in back water of a ZLD based Kraft Paper Mill operating on ZLD without ETP operation is :

Pollution load	**Range**
TDS, g/l	35 – 50
COD, g/l	24- 35
BOD, g/l	16 - 23

- Based on the studies conducted the average TDS , COD & BOD level in back water of a waste paper based Newsprint Paper Mill operating on ZLD without ETP operation is :

- ❑ The mills need to operate the conventional ETP equipped with tertiary treatment system for having less impact on product quality and machine runnability.
- ❑ Recently some mills operating on ZLD on CPPRI recommendations have incorporated biomethanation plant in the backwater loop which has resulted achieving optimum COD < 5000 mg/l resulting in elimination of odor in mill environment and paper as well as reduction in breakdown

Pollution load	**Range**
TDS, g/l	6-8
COD, g/l	4-7
BOD, g/l	1.5-3.0

- ❑ The mills operating on ZLD should also :

- Maintain daily record / log book of raw material (waste paper) consumption , chemical consumption (process & ETP separately) , paper production , energy consumption (process & ETP separately)
- Have maximum 2 borewell (1 in Operation & 1 Stand by).
- Operational flowmeter with totalizer on borewell
- Record daily fresh water consumption (initial reading & final reading) along with daily production in tpd in log book (in m3 / day and m3/ t paper) duly signed daily by authorized signatory / competent authority.
- Install appropriate flow meter / flow measuring device to monitor the volume of backwater generation
- Install a flow meter with totalizer on the recycling pipe line and the flowmeter should be connected to State / CPCB Server
- Install PTZ camera at Sedicell / back water storage tank from where the back water recycled , backwater recycling flow meter as well as at ETP (if available)
- The success of the case study of the RCF based kraft paper mill operating on ZLD in addressing the contentious issues related to ZLD operation specially odour in paper and

paper products by incorporation of effluent treatment system comprising of anaerobic treatment and aerobic treatment in back water loop has set an example for other similar mills operating on ZLD / wishing to switch over to ZLD. The reduction / optimisation of pollution load specially TDS, Calcium, COD, VFA etc has helped the ZLD based RCF paper mills in overcoming the bottlenecks in ZLD operation like adverse impact on product quality, machine runnability, VFA and odour in paper and surrounding environment. The co-generation of biogas is an additional advantage along with water conservation and elimination of wastewater discharge.

- Incorporation of chlorine dioxide dosing into head box / paper machine Silo tank has shown encouraging results in terms of reduction in odor in paper and back water circulating in closed loop

---

Chapter 1

Background , Objective & Methodology of the Project

+

Chapter 1

Background , Objective & Methodology of the Project

1.0 Backgound of the Project

The Project **Development of Protocol for Evaluating the Feasibility of Zero Liquid Discharge in RCF Based Pulp & Paper Mills** , funded by **Research Steering Committe for Pulp , Paper & Allied Industries (RSC-DCPPAI)** was formulated in the perspective of need by regulatory authorities to develop a protocol so as to validate / verify the feasibility of **Zero Liquid Discharge (ZLD)** status as claimed by RCF based Kraft Paper Mills in various parts of the country .

Zero Liquid Discharge refers to process where no liquid leaves the mill / plant boundary . Though called zero liquid discharge, still a pulp and paper mill will require at least 1.5 - 2.5 m^3 / t paper as make up water due to steam, evaporation losses , and loss of water as moisture along with finished paper , sludge etc.

The need for ZLD has been advocated in Pulp & Paper Industry mainly due to depletion of ground water level, less availability of surface water, impact on receiving stream due to less flow , stringent new environmental norms under CPCB charter related to fresh water consumption , regulatory pressure to minimize impact on receiving stream . In recent times some RCF based kraft and newsprint based paper mills have claimed to have achieved ZLD status . This project aimed at developing a systematic / methodical protocol to validate the ZLD status of these mills.

Chapter 2

About RCF based Pulp & Paper Mills – An Introduction

Chapter 2

About RCF based Pulp & Paper Mills – An Introduction

2.0 About Indian Paper Industry

Paper is one of the most environmentally sustainable products as it is - **Biodegradable, Recyclable, Renewable** and produced from sources which are **renewable and sustainable.** Indian Paper Industry is unique as it use diverse raw materials and produces diverse range of paper products .

On the basis of **raw materials used** the industry can be classified into :

- **Mills using Woody Raw Materials (+15 varieties of wood species used by pulp and paper mills)**
- **Mills using Non Wood Fibrous Raw material / Agro residues like Bagasse, Rice Straw, Wheat Straw, Grasses/Reeds**
- **Mills using Waste Papers / Recycled Fiber**

However, in today scenario , most of the mills are using mixed raw materials in fiber furnish depending upon raw material availablity to cater the production requirement and customer demand.

Based on the **end products** the industry can be broadly classified into :

- **Mills producing unbleached grade of paper (Kraft Paper / packaging grade of paper)**
- **Mills producing Bleached grade of Paper (Writing Printing / Duplex Board)**
- **Mills Producing Specialty Grade of Paper (Tissue , Food Grade etc)**

Recently while revising the environmental norms under **Charter for Water Recycling & Pollution Prevention in Pulp & Paper Industries of Ganga River Basin**, CPCB broadly classified the mills into following categories

1. **Wood Based Pulp & Paper Mills producing Bleached Grade of Paper (Category A1)**
2. **Wood Based Pulp & Paper Mills producing Unbleached Grade of Paper (Category A2)**
3. **Agro based Pulp & Paper Mills producing Bleached Grade of Paper (Category B1)**
4. **Agro based Pulp & Paper Mills producing Unbleached Grade of Paper (Category B2)**
5. **RCF based Pulp & Paper Mills producing Unbleached Grade of Paper (Category C2)**
6. **RCF based Pulp & Paper Mills producing Bleached Grade of Paper (Category C1)**
7. **Mills producing Specialty Grade of Paper (Category D)**

2.1 Indian Paper Industry – A Brief Profile

The overall Indian Paper Industry Profile is summarized in **Table 2.1.**

Table 2.1 Profile of Indian Paper Industry(2020—2021)

No. of Mills	**900**
Total Installed Capacity, million tons	**29.11**
Operating Installed Capacity , million tons	**23.99**
Production of Paper, Paperboard and Newsprint , million tons	**21.36**
Capacity Utilization, %	**~89**
Operational Units	**526**
Per capita Consumption (kgs)	**15.63**
Contribution From Different Segments (million tons)	

Wood Based	Agro Based	RCF Mills
3.91	1.16	16.29

Source: Census Survey of Indian Paper Industry

The share in terms of percentage of overall production is indicated in **Fig 2.1.**

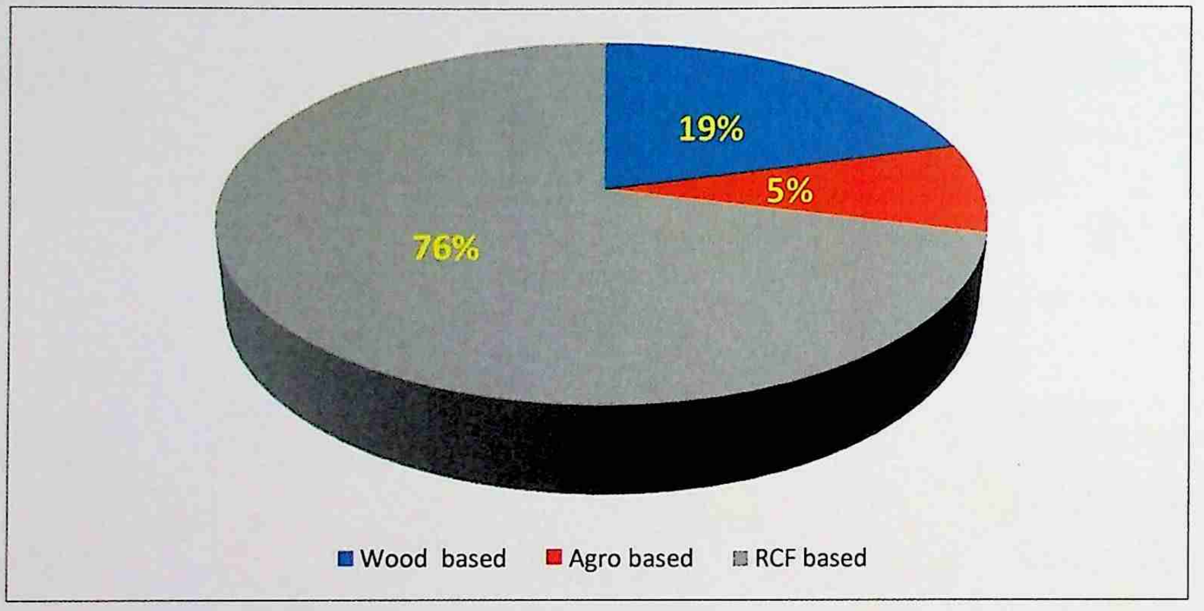


Fig 2.1 Percentage Paper Production Share (Raw Material Basis)

As indicated above due to raw material shortage and comparative simplicity in process operation there has been a paradigm shift in raw material furnish from wood / agro to recycled fiber for paper production .

2.2 General Pulp & Paper Making Process in RCF based Paper Mills

The RCF based Pulp & Paper making process as indicated in **Fig 2.2 & 2.3** is comparatively simple compared to general pulp and paper making process used by Wood & Agro based Pulp & Paper Mills as depicted in **Fig 2.4.**

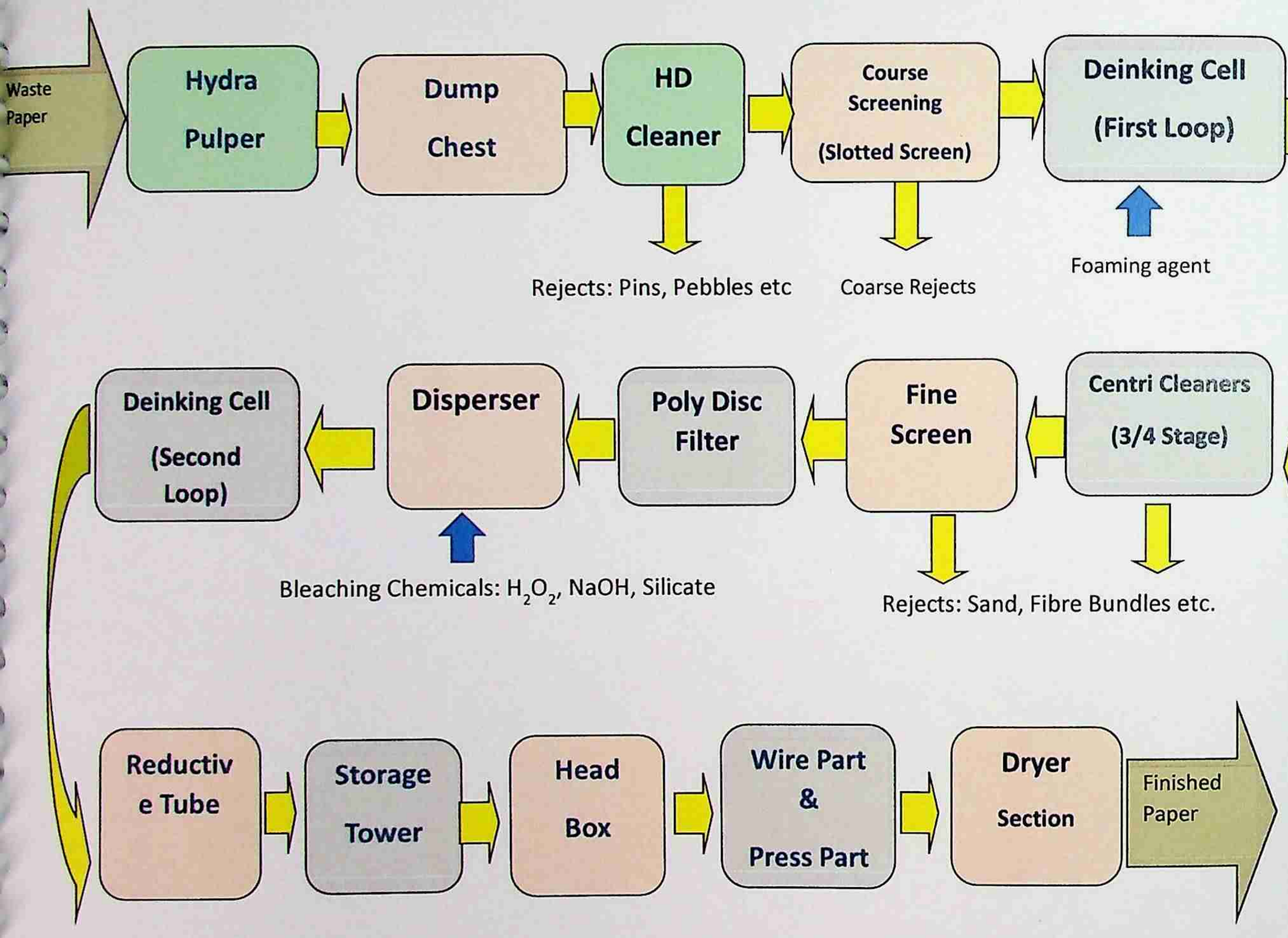


Fig 2.2 General Pulping & Paper Making Process in a RCF Based Writing & Printing Grade Paper Mill

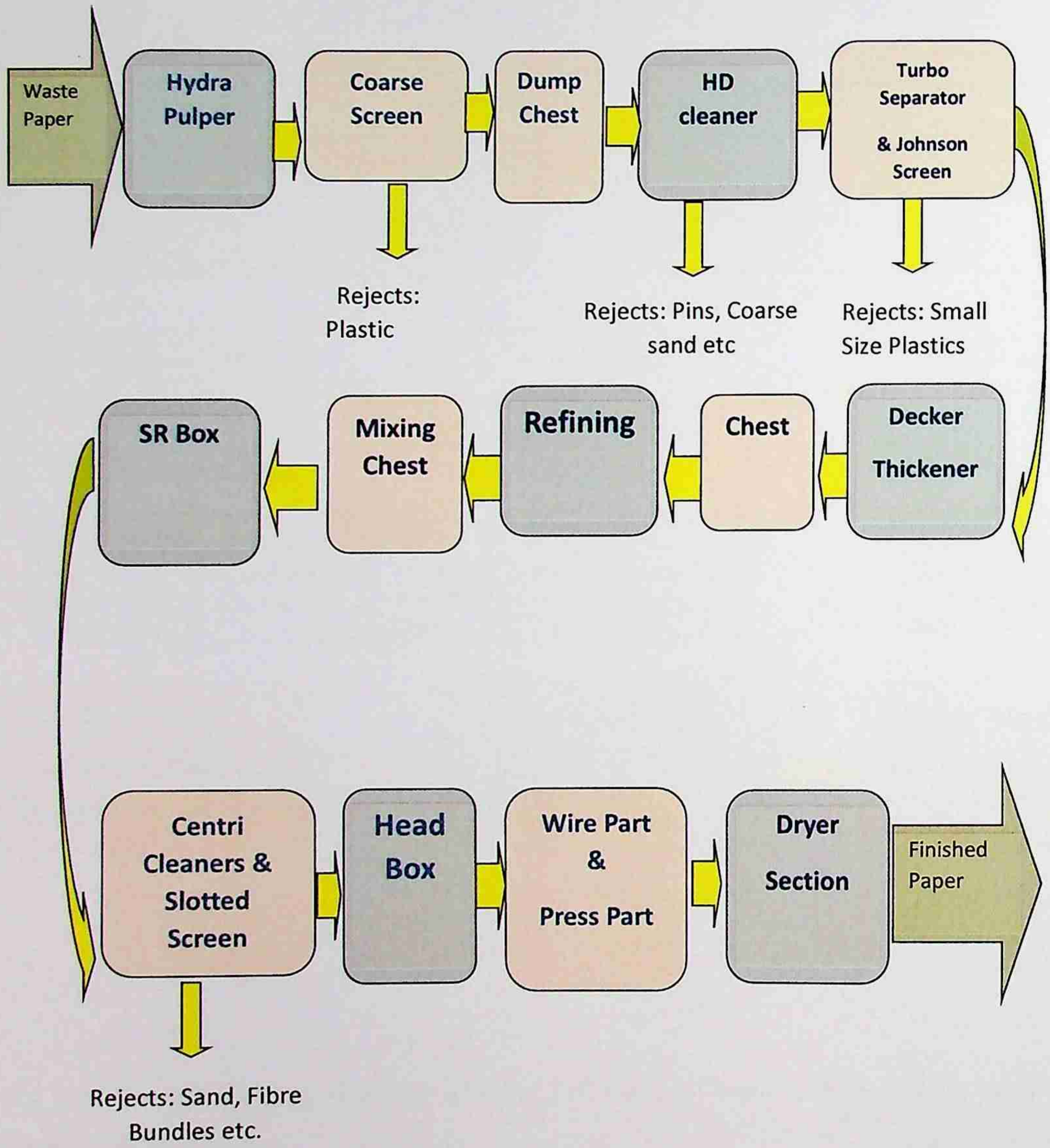


Fig 2.3 General Pulping & Paper Making Process in a RCF Based Kraft Grade Paper Mill

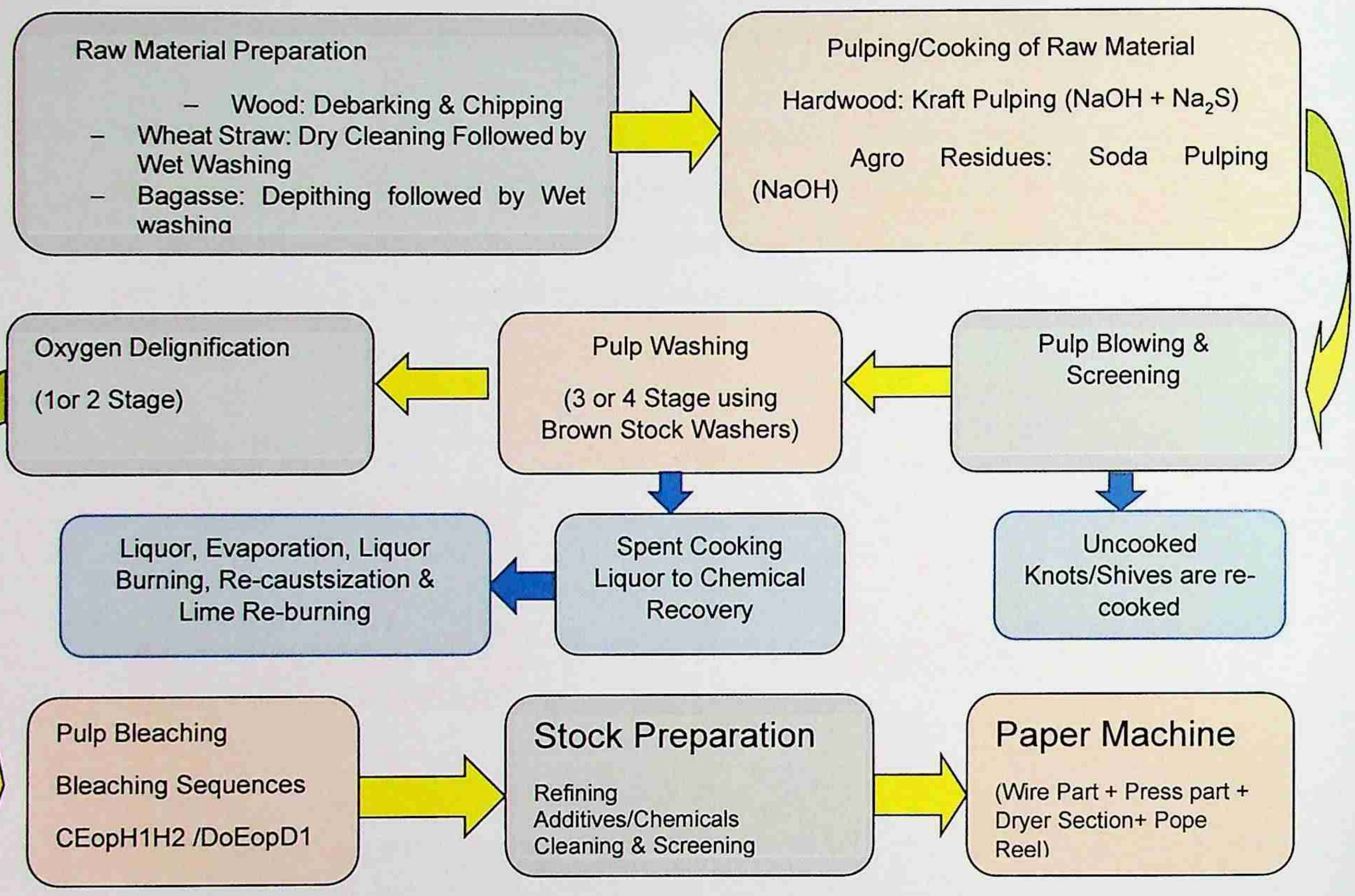


Fig 2.4 General Pulping & Paper Making Process in a Wood & Agro Based Pulp & Paper Mill

Effluent Treatment Plant (ETP)

Almost all the pulp and paper mills in general have similar type of configuration for effluent treatment plant which based on activated sludge process . The ETPs in general mainly comprise of **equalization tank , primary clarifier , aeration tank , secondary clarifier , tertiary treatment system , and sludge dewatering system.(Fig 2.5)**

Wastewater generated from process operations like pulp mill, paper machines, power / steam boilers is usually collected in a **Equalization Tank (Fig 2.6)** to avoid fluctuation in pollution load entering ETP and subsequently clarified in a **Primary Clarifier (Fig 2.7)** for removal of suspended solids to reduce pollution load of the effluent stream entering aeration tank .

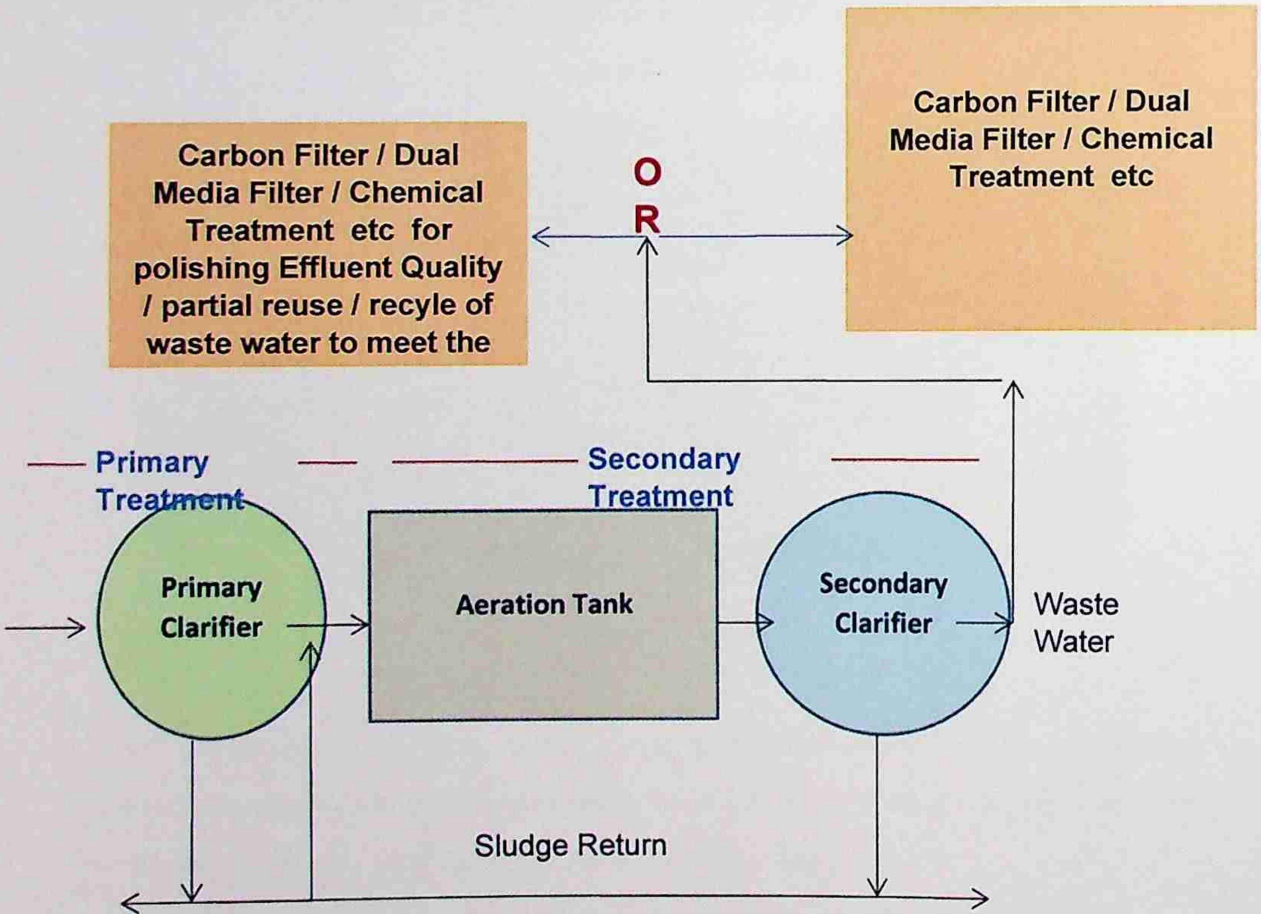


Fig 2.5 Effluent Treatment Plant in Pulp & Paper Mills

Fig 2.6 EqualizationTank

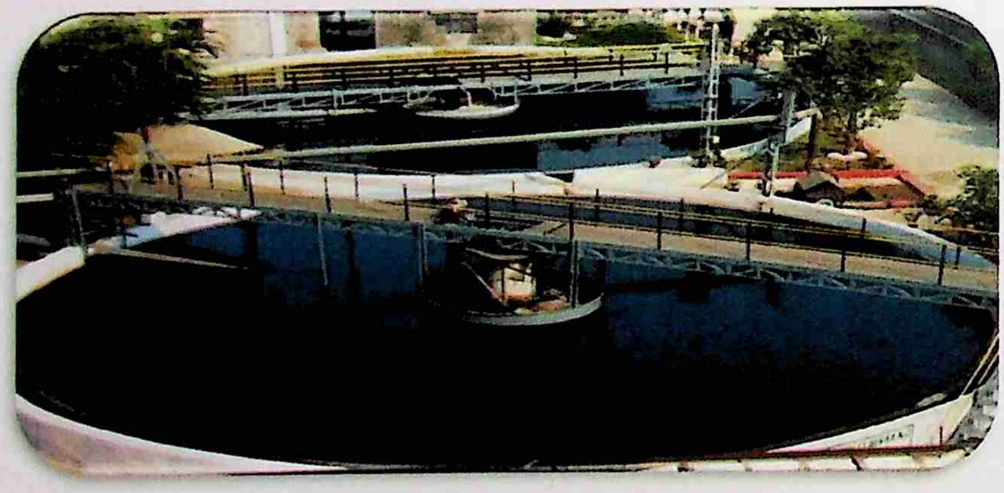


Fig 2.7 Primary Clarifier

After clarification, the waste water is pumped into **Aeration Tank** equipped with **diffused aerators / surface aerators** to maintain the dissolved oxygen level required for proper metabolic activity of microbial culture. (**Fig 2.8**).

Fig 2.8 Aeration tank

The overflow of wastewater from aeration tank than goes into secondary clarifier **(Fig 2.9)** for settling of biomass. The settled biomass is recirculated to aeration tank to maintain the adequate MLSS level in aeration tank while the rest is disposed off.

Fig 2.9 Secondary Clarifier

The clarified effluent is further subjected to tertiary treatment (**Fig 2.10**) involving **dual media filter / sand filter / activated carbon filter** and / or **chemical treatment** to further polish the effluent quality and meet the stipulated norms.

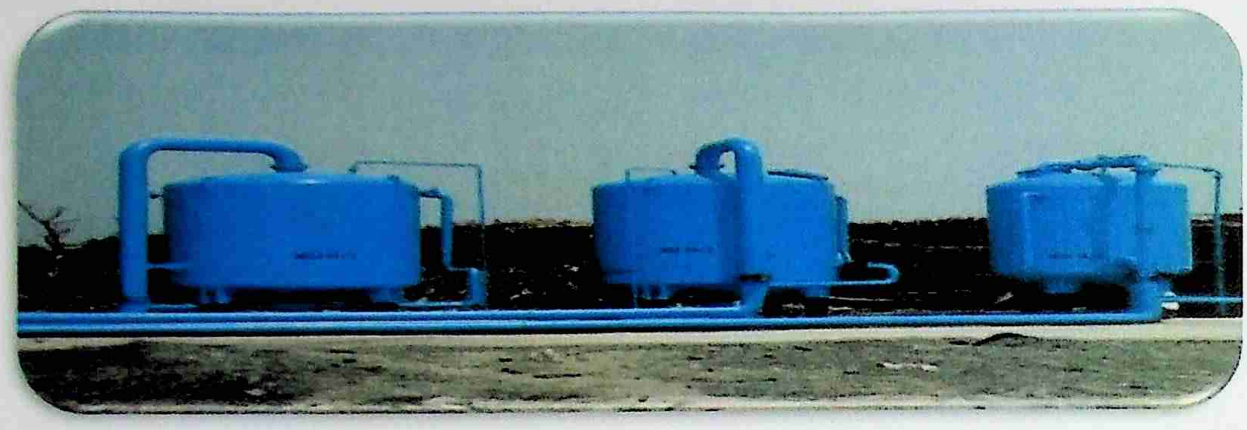


Fig 2.10 Tertiary Treatment System

Chapter 3

About Zero Liquid Discharge - An Introduction

Chapter 3

About Zero Liquid Discharge - An Introduction

3.0 About Zero Liquid Discharge

The conventional **'Physico-Chemical-Biological'** treatment in various industrial sector including pulp and paper mills does not remove TDS and color significantly in the treated effluent thus limiting its reuse / recycle back into the process.

Zero Liquid Discharge (ZLD) is a system consisting of unit processes or unit operations or their combination, such that there is no discharge of liquid effluent from an industry, process plant, etc. ZLD status of a unit is a reflection of the fact that the effluent generated is effectively treated, recycled and reused by the mill / unit and no liquid is discharge outside its premises.

3.1 Historical Perspective

ZLD technology was initially developed for power plants, in USA and later implemented globally. During early seventies, high salinity of the River Colorado due to discharge from power plants, developed the need for imposing Zero Liquid Discharge. Regulators were primarily concerned with discharge from scrubbers and cooling tower blow downs in power plants. First ZLD installed was of 114-454m^3/hour capacity , based on evaporation/crystallization. Initially low-cost ponds were used for evaporation of Reverse Osmosis (RO) reject. In Germany, ZLD systems for coal-fired power plants were a result of strict regulations and laws in the 1980s.

3.2 Benefits of ZLD

- Installation of ZLD technology facilitate water conservation through recycling and reuse of process water recovered from waste water
- Helps in improving receiving stream water quality due to elimination / minimization of waste water discharge
- In addition to receiving streams ecology , soil salinity and groundwater nearby discharging units are also not affected.

Reusing & Recycling of Treated effluent without technology intervention leads to various issues as summarized as under :

Impact of Dissolved Collidal Substances / Total Dissolved Solids Build up	❑ **Problems of Scales (carbonates and silicates)** ❑ **Corrosion (sulfates, chlorides, iron and aluminum ions)** ❑ **Brightness reversion (due to Fe^{2+})** ❑ **Bacterial growth due to higher dissolved organics** ❑ **Odour problem in paper** ❑ **High TDS, COD , BOD and Color in effluent** ❑ **Poor drainage** ❑ **Poor web formation** ❑ **Decrease in strength properties of paper** ❑ **High ash** ❑ **Increase in water absorptiveness of paper (Cobb)**
Impact of Temperature Increase	**Temperature increase in the closed loop / circuit may lead to :** ❑ **Accumulation of pitch on machine fabric or press felt leading to negative impact on paper making process and quality** ❑ **Create corrosive conditions in presence of high concentration of chlorides and sulphates** ❑ **Promote Bacterial growth which may impact Paper Quality** ❑ **Decrease in Ph value of backwater due to increase in VFA**

Impact of TSS build up	❑ **Plugging of shower nozzles, small lines and felts** ❑ **Deposit formation (biological . Non biological) and Intensification of biological slime** ❑ **Lower filtration capacity of fiber recovery units.** ❑ **Poor Drainage** ❑ **Increase demand of retention aids**
Increase in Anionic Trash and other materials	❑ **Increase the demand of wet end chemicals added to increase the retention of fibers** ❑ **Use of waste paper introduces adhesives , residues , tapes, hydrolyzing sizing agents which in a water system produce particulate component that tend to stick to paper machine parts and final product causing many problems**
Other Impacts	❑ **Low life of paper machine felt and wire** ❑ **Increase in broke** ❑ **Inorganic fouling in process equipments in different unit operations frequently cause** – **Downtime to clean the fouling causing production downtime** – **Quality defects in end products**

3.5 ZLD in RCF Based Kraft Paper Mills

In recent times with implementation of **Charter for Water Recycling & Pollution Prevention In Pulp & Paper Industries in Ganga River Basin** the fresh water consumption and waste water targets for RCF based Pulp & Paper Mills has been formulated as under :

RCF based Pulp & Paper Mills Category	**Fresh Water Consumption , m^3 / t paper**	**Waste Water Discharge m^3 / t paper**
RCF based Pulp & Paper Mills producing Bleached Grade of Paper	15	10
RCF based Pulp & Paper Mills producing Unbleached Grade of Paper	10	6

In context with stringent fresh water consumption and waste water discharge norms as well as well as to reduce cost of ETP operation many RCF based paper mills producing unbleached grade of paper have switched over to Zero Liquid Discharge (ZLD) by complete reuse / recycling of back water without major technology intervention except fiber recovery system.

It is to be noted that inspite of operating on zero liquid discharge still a pulp and paper mill requires 1.5 – 2.5 m^3 / t paper as make up water due to steam, evaporation losses , and loss of water as moisture along with finished paper , chemical preparation , sludge etc

Chapter 4

Case Studies

Chapter 4

Case Studies

To study and develop the protocol for evaluating feasibility of ZLD in RCF based paper mills following mills were selected as case study under the project

1. **Mill A (RCF Based Produced Bleached Grade (Writing & Printing) Grade Paper**
2. **Mill B (RCF Based Mill Producing Newsprint Grade of Paper)**
3. **Mill C (RCF Based Mill Producing Kraft Paper)**

4.1 Case Study I : Mill A (RCF Based Produced Bleached Grade (Writing & Printing Grade) Paper

Process Details

The mill has a Hicon pulper for waste paper processing. The waste paper pulp is subjected to cleaning and screening through a combination of Poire, high density cleaner, VSM and CLB followed by deinking using floatation cell, poly disc filter and disperser. Cleaned, screened and deinked pulp is mixed with chemicals & additives to achieve desired product specifications. The pulp stock after passing through pressure screen is sent to paper machine for production of writing & printing grades of paper.

The mill has 02 borewells with a permitted withdrawal quantity: 1911 KLD. The electromagnetic flow meters are provided at each borewell to monitor the fresh water consumption . The average fresh water consumption of the mill 12 m^3 / t paper.

The unit has a full fledged ETP up to tertiary treatment . The dimensions of each unit are summarized in **Table 4. 1**

Table 4.1 : ETP Design Specification

Unit	Dimensions	Capacity m^3
Equalization tank	16 m x 8 m x 3.25 m	416 m^3
Sedicell	-	250 m^3/hr
Primary Clarifier	Dia: 18.0	826 m^3

	SWD 3.25 m	
Aeration Tank (2 Nos.)	**30 m x 24 m x 3.25 m** **14 m x 24 m x 3.5 m**	**3,516 m^3**
Secondary Clarifier	**Dia: 18.0 m** **SWD 3.25 m**	**826 m^3**
Tertiary Treatment System **Dual Media Filter (02)** **Spray filter**	**--** **--**	**100 m^3/hr each** **80 m^3/hr**
Sludge Dewatering System- Decanter Centrifuge- 2 Nos. & Belt Press- 1 No.	**Available**	**12 tonnes dry solids per day**

The ETP Units are indicated in **Fig 4. 1**

Sedicell **Equalization tank** **Primary Clarifier**

Aeration Tank **Secondary Clarifier** **Tertiary Treatment**

Fig 4.1 ETP units at Mill A

Studies were initiated with initial fresh water consumption of **12 m^3 / t paper** followed by increased recycling so as to achieve fresh water consumption of **10 m^3 / t paper** as well **as 8 m^3 / t paper**. The impact of the reuse / recycling of back water without technological intervention was also evaluated and is summarized in **Table 4.2**

Table 4.2 Impact of Increased Reuse / Recycling of Back Water

S. No.	Water Consumption, m^3/t paper	TDS, mg/l	COD, mg/l	BOD, mg/l
1.	Fresh water consumption 12 m^3/Ton of Paper @ 30% treated water/back water recycling	1,300	800	280
2.	Fresh water consumption 9 -10m^3/Ton of Paper @ 50% treated water / back water recycling	2,200	1,000	400
3.	@ 80% treated water/back water recycling (fresh water consumption 7 - 8 m^3 /Ton of Paper.	5,000	1,400	700
4.	Paper quality parameters • Brightness • Cobb	 80 22	 78 25	 75 28
5.	Chemical consumption and other conditions • Clothing chocked, days. • Shower nozzles chocked, days. • Chemical consumption	8 30 Normal	5 8 Increased @ 20 %	2 4 Increased @ 40 %

As indicated above the build up of TDS, COD and BOD due to increased recycling / reuse of back water without any technology intervention adversely impacted the brightness and cobb properties of the paper produced as well as led to increased chemical consumption (retention aids etc) and choking of shower nozzles short life of felt

As a result the mill discontinued its plan for increased reuse / recycling of back water and went back to 30 % reuse / recycling of back water in its process.

Conclusions

It is difficult to achieve ZLD without technological intervention in a mill producing Bleached Grade of Paper

4.2 Case Study II : Mill B (RCF Based Mill Producing Newsprint Grade of Paper)

S.No	Particulars of the Mill	Details
1	Production Capacity, tpd	90 newsprint of high bulk (2.2 – 2.6 cm^3/gm) of grammage 46 - 50 gsm
2	Raw material	Indigenous old newspaper
3	Period of ZLD Operation	4 years
4	Fresh Water Consumption	1.94 m^3 / t_{paper} 175 m^3/day

Manufacturing Process

The paper manufacturing process includes processing of waste paper through pulper to produce pulp. The waste paper pulp is further screened & cleaned through two stage turbo separators, Johnson screen and centric leaners. Then, pulp consistency is maintained as per required grammage. The general layout of manufacturing process for paper making is indicated in **Fig. 4.2**

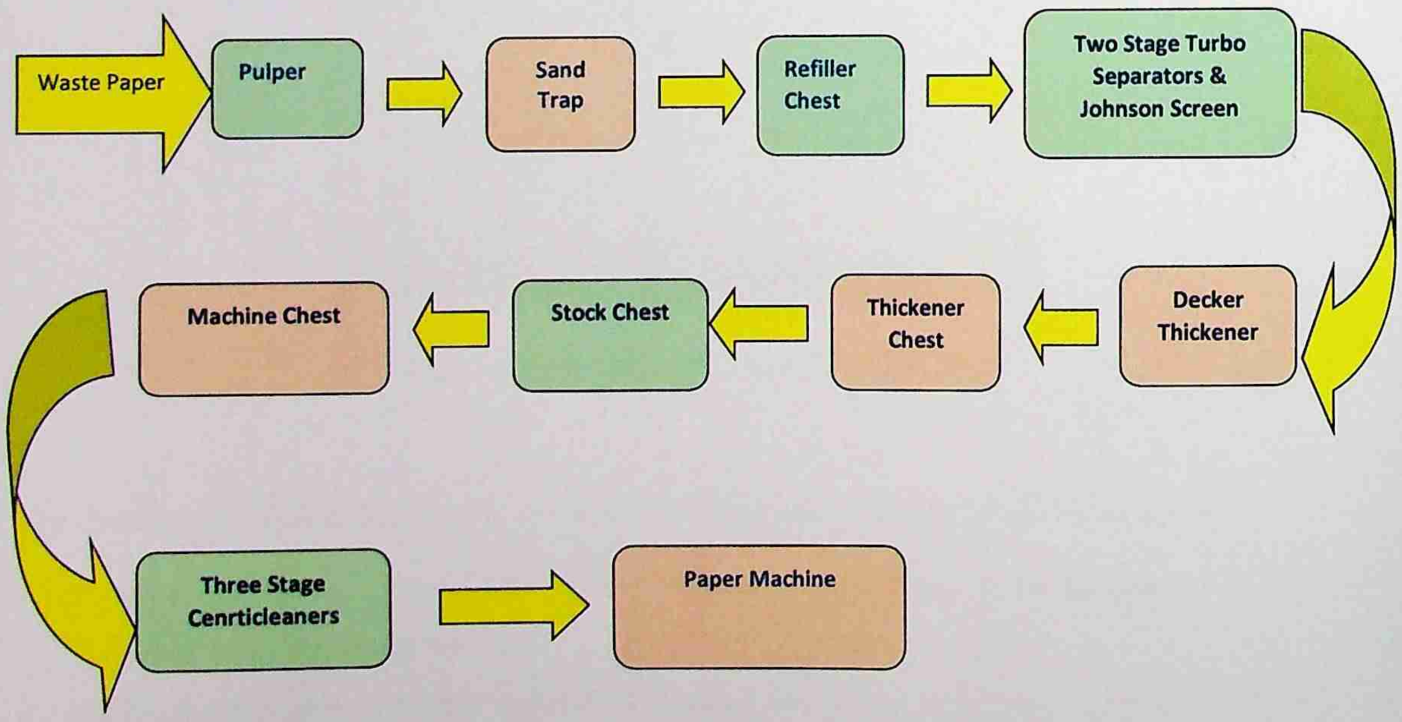


Fig 4.2 General Paper Manufacturing Process of Mill B

ZLD System Adopted by the Mill

After fiber recovery through sedicell, the backwater generated is stored in storage tank and reused either through spray filter (for use on paper machine) or directly in other pulp mill operations The mill has discontinued the use of ETP as indicated in **Fig 4.3**

Fig.4.3 : Closed ETP at Mill

A PTZ camera is also installed to monitor the reuse / recycle of the back water **(Fig 4.4)**

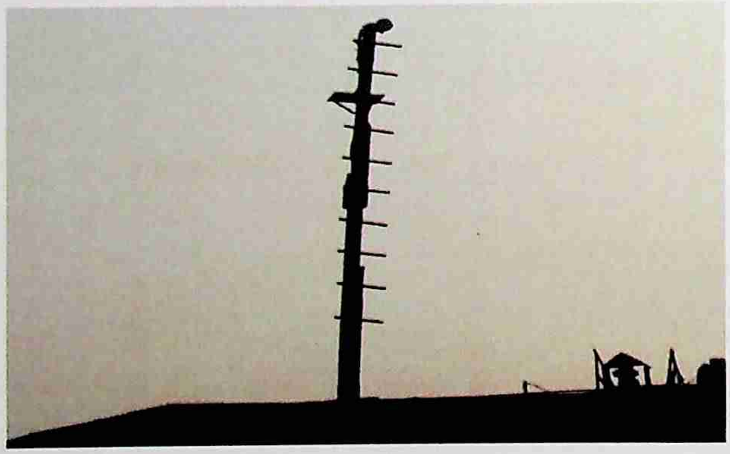


Fig 4.4 Web Camera facing Closed ETP

The multi pronge methodology was adopted to validate the feasibility of ZLD is as under:

- **Monitoring of TDS, COD and BOD Level Accumulated in Back Water Samples Collected from Different Sources**
- **Comparative Study of Water Intake v/s Water Loss**
- **Material Balance Study with Respect to Inputs & Outputs During Paper Making**
- **Study in Laboratory Simulating Mill Conditions to Estimate the Constant level of TDS, COD and BOD accumulated in Back Water Circulating in Closed Loop Due to Zero Liquid Discharge**

Monitoring of TDS, COD and BOD Level Accumulated in Back Water Samples Collected from Different Sources

The TDS, COD and BOD level in back water samples generated from different mill operations as collected and analyzed at different interval is summarized in **Table 4.3** below:

Table 4.3 Build up of Pollution Load @ Various Intervals of Time

S. No.	Period	Sources		TSS, mg/l	TDS, mg/l	COD, mg/l	BOD, mg/l
1.	1st sampling	Paper Machine # 1	Wire Tray Back Water	2316	6258	4355	2173
		Paper Machine # 2	Wire Tray Back Water	2426	6488	4332	2279
		Paper Machine # 3	Wire Tray Back Water	2657	6356	4546	2122
		Sedicell Inlet		2196	6419	4409	2021
		Sedicell Outlet		403	6393	3112	1798
		Spray filter Outlet		***188***	***6316***	***3001***	***1687***
2.	2nd sampling	Paper Machine # 1	Wire Tray Back Water	2966	6344	4209	1944
		Paper Machine # 2	Wire Tray Back Water	2612	6233	4321	2138
		Paper Machine # 3	Wire Tray Back Water	2294	6493	4177	2157
		Sedicell Inlet		2435	6397	4249	2166
		Sedicell Outlet		359	6266	3139	1734
		Spray filter Outlet		***202***	***6225***	***2997***	***1712***

As indicated above and in **Fig 4.5** below the TDS , BOD & COD level was nearly stable during the period of sampling indicating mill operation on ZLD

Fig 4.5 Nearly Constant Level of TDS , COD & BOD in back water

Water Intake v/s Water Loss

Further water losses per day were estimated during the paper making and compared to the total water intake i.e.182 m^3/day which is used as make up water to compensate water loss as evaporation from dryer section, as steam loss, as back water carryover with solid rejects, as back water used in ash quenching and as miscellaneous losses. As indicated in **Table 4.4** the water intake was similar to the water losses estimated

Table 4.4 Comparative Estimation of Water Intake & Water Losses

Water Intake, m^3/day		Water Loss, m^3/day	
Fresh Water added as make up water in back water tank	120	Evaporation at Dryers	114.5
Boiler House	55	Steam Loss	55
With Waste Paper	7	Back Water with Solid Rejects	3

		Water with Finished Paper as Moisture	**4.5**
		Miscellaneous/Open Loss	**5**
Total Water Intake, m^3/day= 182		**Total Water loss, m^3/day = 182**	

Material Balance with Respect to Inputs & Outputs During Paper Making:

The major inputs involved in manufacturing of 90 tonnes/day newsprint are summarized in **Table 4.5** and the Material Balance carried out is depicted in **Fig 4.6**

Table 4.5 Material balance of Mill B

Inputs, tonnes/day (OD Basis)		**Outputs, tonnes/day (OD Basis)**	
Waste Paper	**88** (95 @ 7.5 % moisture)	Finished Paper	**85.5** (90 @ 5.0 % moisture)
Additives/Chemicals	Nil	Solid Rejects & TDS in back water	**3.241**
TDS Carryover with Finished Paper (Due to reuse of back water)	**0.741**		
Total	**88.741**	**Total**	**88.741**

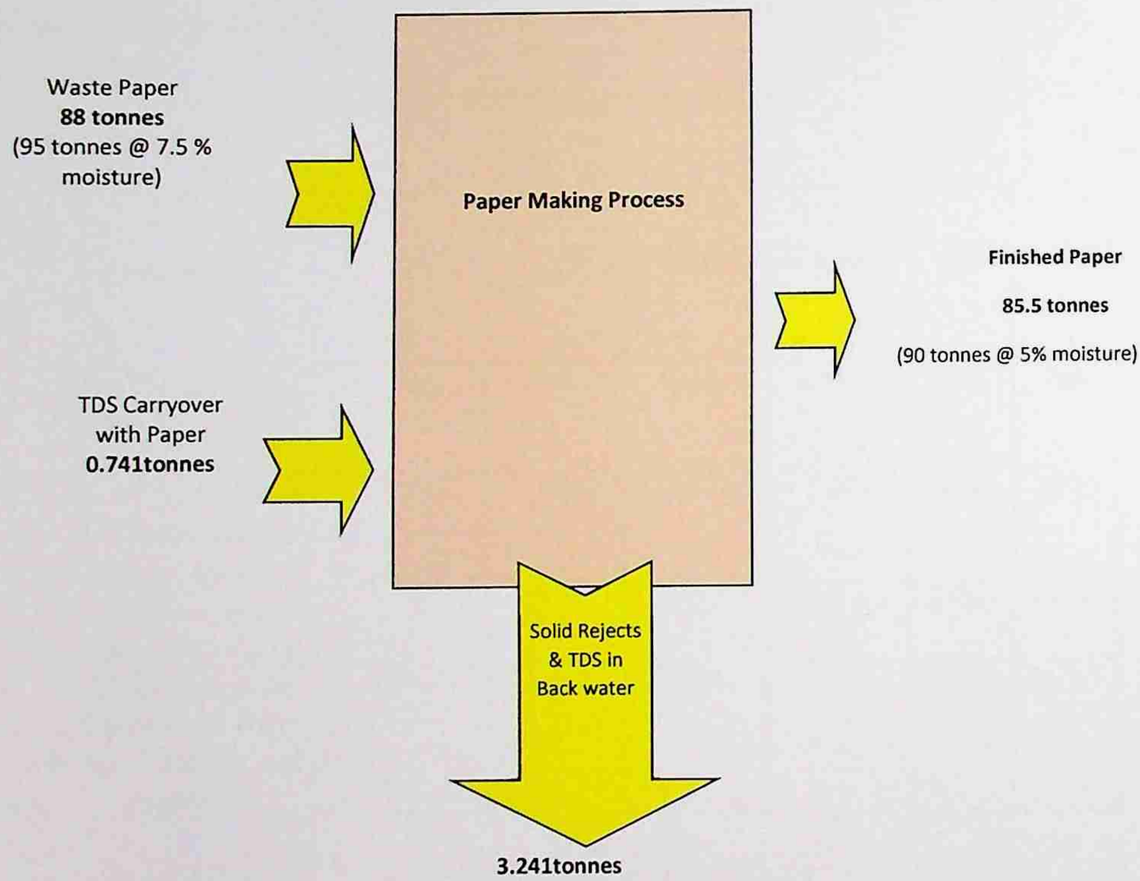


Fig. 4.6 Existing Material Balance in Paper Making of Mill B

Study in Laboratory Simulating Mill Conditions to Estimate the Constant level of TDS, COD and BOD accumulated in Back Water Circulating in Closed Loop Due to Zero Liquid Discharge

Further studies were carried out at CPPRI laboratory to estimate the TDS, COD & BOD generation/build up in back water simulating the existing mill conditions. The basis for study is as under :

- Raw material used, tonne/day = **88 (95 @** 7.5 % moisture)
- TDS generation from waste paper, kg/d = **766 (8.7 kg/t $_{\text{waste paper}}$)**
- The COD generation from waste paper, kg/d = **370 kg/d (4.2 kg/t $_{\text{waste paper}}$)**
- The BOD generation from waste paper, kg/d = **211 kg/d (2.4 kg/t $_{\text{waste paper}}$)**

The detailed calculation related to continuous accumulation of TDS, COD & BOD in backwater along with their concentration at which the addition of TDS, COD and BOD in back water per day equals to their loss due to carryover with finished paper & solid rejects is indicated in **Tables 4,6** below:

Table 4.6 TDS Generation & Loss

Particulars	Day					
	1^{st}	15^{th}	30^{th}	45^{th}	60^{th}	75^{th}
TDS Generation, kg/day (Constant)	766	766	766	766	766	766
Back Water Volume in Closed Loop, m^3/day (Constant)	1000	1000	1000	1000	1000	1000
TDS Concentration in Back Water, mg/l	770	5520	6360	6490	6515	6518
TDS loss, kg/day (Carryover with Finished Paper, solid rejects)	90.0	648.5	748	763.2	765.6	765.9

Table 4.7 COD Generation & Loss

Particulars	Day					
	1^{st}	15^{th}	30^{th}	45^{th}	60^{th}	75^{th}
COD Generation, kg/day (Constant)	370	370	370	370	370	370
Back Water Volume in Closed Loop, m^3/day (Constant)	1000	1000	1000	1000	1000	1000
COD Concentration in Back Water, mg/l	370	2670	3070	3140	3147	3149
COD Loss, kg/day (Carryover with Finished Paper & solid rejects)	43.5	313.2	316.3	368	369.79	369.97

Table 4.8 BOD Generation & Loss

Particulars	Day					
	1st	15th	30th	45th	60th	75th
BOD Generation, kg/day (Constant)	211	211	211	211	211	211
Back Water Volume in Closed Loop, m^3/day (Constant)	1000	1000	1000	1000	1000	1000
BOD Concentration in Back Water, mg/l	210	1520	1750	1790	1795	1796
BOD Loss, kg/day (Carryover with Finished Paper & solid rejects	24.8	178.6	206.0	210.2	210.88	210.98

It is clear from above tables that the concentration at which the addition of TDS, COD and BOD in back water per day equals to their loss due to carryover with finished paper & solid rejects is about **6.5 gpl , 3.14 gpl & 1.79 gpl respectively.**

Similarly the mass balance for TDS addition and TDS loss , COD addition and COD loss & **BOD Addition and BOD Loss** was evaluated and is indicated in **Table 4.9** as under:

Table 4.9 Mass Balance of TDS Generation and TDS Loss

TDS addition, Kg/day		TDS loss, Kg/day	
Through waste paper	766	Carryover with finished paper	741
		Carryover with solid rejects	19
		Total	**760**

Table 4.10 Mass Balance of COD Addition and COD Loss

COD Buildup, kg/day		COD loss, kg/day	
Through waste paper	370	Carryover with finished paper	357
		Carryover with solid rejects	9
		Total	**366**

Table 4.11 Mass Balance of BOD Addition and BOD Loss

The mass balance for COD addition and COD loss was evaluated as under:

BOD Buildup, kg/day		BOD loss, kg/day	
Through waste paper	211	Carryover with finished paper	204
		Carryover with solid rejects	5
		Total	**207**

Observations

The fresh water consumption as per mill record is around **175 m^3/day (1.94 m^3/tonne $_{paper}$)** which is used as make up water only.

The major water losses include :

- The combined water loses as evaporation from dryer section of all the three paper machine is around 114.5 m^3/day (1.27 m^3/t paper)
- The steam loss and other losses during paper making process i.e. 67.5 m^3 / day (0.75 m^3/t paper)
- The steam consumption at paper machines is around 2.5 tonne / t paper, which is comparatively high probably high moisture in the paper sheet (57 % w/w) at dryer inlet.
- The fresh water consumption i.e. 1.94 m3/t paper and fairly constant level of TDS (~ 6200 mg/l) , COD (~ 3000 mg/l) and BOD (~1700 mg/l) measured in back water (Spray

Filter Outlet) at different time interval indicates the possibility of mill operating on Zero Liquid Discharge.

- The lab scale studies on estimation of pollution load generated by pulping of waste paper used by the mill and subsequent theoretical estimation of buildup of the pollution load indicates that the concentration at which level of TDS, COD and BOD in back water equals to their loss as carryover with finished paper & solid rejects is about 6.5 gpl , 3.14 gpl & 1.79 gpl respectively which is in close proximity to the existing level of TDS , COD and BOD analysed in the back water collected i.e 6.2 gpl , 3.0 gpl and 1.7 gpl respectively. This further indicates mill's operation at ZLD.

A decline in brightness of newsprint to from 44 % ISO to 42 % ISO as well as reduction in wire & felt life by 15 – 20 % has been observed which further indicates adverse impact on paper quality and process operation probably due to mill switch over to ZLD without any major technological intervention

An electromagnetic flow meter has already been installed to monitor the volume of back water reused / recycled into the process.

4.3 Case Study III : Mill C (RCF Based Mill Producing Kraft Grade of Paper)

The Mill C is manufacturing Kraft Paper from 100% waste paper (Indigenous & imported). The Mill has two paper machines of production capacity 100 & 50 TPD. The mill is manufacturing Kraft paper of burst factor from 16 to 35 depending on market requirement. At present the mill is operating at around 67% of its production capacity and machines are being operated for manufacturing of 100t/d of different quality of kraft paper. The paper machine I is used to produce kraft paper (BF 14-16) in the GSM range of 100 -180 g/m^2 and the paper machine II is used to produce multilayer kraft paper of high BF (22-35)

MANUFACTURING PROCESS

The mill uses indigenous and imported waste paper for production of kraft paper. The imported waste paper which is high wet strength paper is difficult to slush in hydrapulper therefore the mill is using 3 Nos of digester for cooking of imported waste paper. Back Water from ETP is used to makeup bath ratio around 1:2.5 then it is steamed for 1-2 hours to attain a temperature of 125-130°C at a steam pressure of 3.5-4.0 kg/cm^2. The retention time at top temperature is around ~2 hrs. Thereafter the pulp is dumped and sent to hydrapulper through a conveyer for its slushing. From hydrapulper the pulp is passed through poir screen, high-density cleaner, turbo separator and hill screen. The thickened pulp from hill screen is sent to stock preparation for addition of rosin, alum and dyes and from stock preparation the pulp is sent to paper machines. Indigenous waste paper is directly fed to hydrapulper and indigenous waste paper is used mostly for paper production in Paper Machine I (low BF) and for producing bottom layer to multilayer Kraft paper produced in Paper Machine II (High BF).

The mill has two numbers of bore well for extraction of the ground water to meet fresh water requirement of the mill for manufacturing of kraft paper. Each bore well is equipped with online magnetic flow meters for recording of volume of fresh water extracted. The fresh water is collected first in a **Reservoir Tank**. From reservoir it is pumped to an **Overhead Tank** for its further distribution to various paper making sections. Presently the mill is using only one bore well and the second bore well is standby. The fresh water requirement at various sections is indicated in **Table 4.12 :**

Table 4.12 : Fresh water Consumption in Mill C

S. No.	Section	Quantity, m^3 /day	Purpose
1.	Boiler	200 100	-For generation of process steam for ***paper plant*** -For generation of steam for ***particle board plant***

		200	-For production of steam for electricity generation for ***steel plant***
2.	Cooling Tower	150	-For make up of water required for water lost due to evaporation at ***cooling tower***
3.	High pressure showers at paper machine	200	-For cleaning & washing of ***web forming wires & felts at paper machine I & II***
4.	Miscellaneous	250	-For supply of dirking water at mills residential colony for more than 150 families and gardening at colony guest house.
	Total	**1100**	

MEASURES TAKEN FOR FRESH WATER CONSERVATION

The fresh water requirement in paper making process can be reduced, through process optimisation, efficient water usage and reuse of back water to the maximum extent. The mill has already taken considerable measures to reduce water consumption particularly through reuse of back water in pulp mill stock preparation and also in showers at paper machine which is a main area of fresh water requirement. Some of the measures taken by the mill to reduce fresh water requirement are as follows:

a) Reuse of back water in pulp mill & paper machine

- Hydrapulper
- Turbo separator dilution
- Slotter screen dilution
- HD cleaner dilution
- Reject sorter dilution

- Chemical preparation
- Machine chest dilution
- Floor cleaning

b) Reuse of treaded effluent (Primary Clarifier Overflow & part of Secondary Clarifier Overflow)

- Rewinder cooling
- Vacuum Pump Sealing
- Digester makeup
- Hydrapulper dilution
- Reject sorter dilution
- Foam Killing shower
- Ash quenching

Reuse of treated effluent:

The part secondary clarifier overflow (~200 m^3 /d) is passed through filter press having 10μm cloth for filtration of biological solids and then after mixing with fresh water (~ 200 m^3/d) it is service tank it is reused in high pressure showers

- Wire cleaning high pressure shower ***(1 No in PM 1&3 Nos in PM 2)***
- Felt cleaning high pressure shower ***(1 No in PM 1 & 4 Nos of PM 2)***
- Edge cutter high pressure shower in ***PM 1 & 2***
- Knock down high pressure shower at ***PM 1 & 2***

WATER BALANCE

The mill is using ~550 m^3 fresh water for paper making in paper machine I & II and the mill is loosing same amount of water as evaporation loses or carryover with boiler ash/ETP sludge. The water balance of the mill is **Table 4.13**

Table 4.13 Water Balance in Mill C

S No.	Process	Water Requirement, m^3	Water losses, m^3	Remarks
1.	Digester	-	10	-To atmosphere due to leakage/ evaporation of steam
2.	Paper Machine			
	i) Showers	200	-	
	ii) Dryers	-	100	-To atmosphere due to evaporation
3.	Boiler			
	i) Make up water for production of steam required for process and also losses of steam during transportation & leakages	200	-	-
	ii) Water loss due to evaporation	-	120	-To atmosphere due to losses of water during drying of paper sheet
	iii)Ash quenching ***(Back water)***	-	130	- Going along with boiler ash
4.	Turbine make up water at Cooling Tower	150	150	- To atmosphere due to evaporation during cooling of water at cooling tower
5.	Spray at Mill for dust suppression / gardening etc. ***(Back water)***	-	20	- To spray for dust killing as well as horticulture activity inside the plant
6.	ETP sludge	-	20	Carry over with ETP sludge to board mill

Total, m^3	**550**	**550**	

DETAILS OF EXISTING ETP

The effluent treatment plant consists of equalisation tank, Johnson screen, hill screen, primary clarifier (2 Nos), aeration tank, secondary clarifier (2 Nos) filter press ((2 Nos, one for filtration of secondary clarifier overflow and other one for filtration of under flows of primary & secondary settling tanks). The layout of modified ETP is given in **Fig 4.7** and the details are given in **Table 4.14 .**

Table 4.14 ETP Design Specifications in Mill C

S. No.	Unit	Specification	Purpose
1.	Equalisation tank	Cap- 347 m^3	**To avoid variation in effluent characteristics**
2.	Johnson Screen	-	**For removal of plastics polythenes and other coarse materials**
3.	Hill Screen	4.2x1.2 m^3	**For recovery of fibres**
4.	Primary clarifier	I - Cap : 1293 m^3 II - Cap : 290 m^3	**For removal of suspended materials**
5.	Aeration tank	Cap : 2535m^3 ***Aerator : 6x25HP***	**For removal biodegradable organic materials**
6.	Secondary clarifier	I - Cap : 907 m^3 ***(Standby)*** II- Cap : 615 m^3	**For removal of suspended matter (biological solids)**
7.	Filter Press	No. of plates – 52 Size 12.m X 1.2m 2 Nos	**(i)To increase dry solids of ETP sludge** **(ii)To remove fine suspended particles from secondary treated water for its reuse at high pressure showers**

TREATMENT OF EFFLUENT

The combined waste water consisting mainly excess paper machine back water (overflow of paper machines 1& 2 back water tank), pulp mill back water etc is collected in equalisation tank. From equalisation tank, effluent is passed through a Johnson screen for removal of coarse materials & then to a hill screen having 40 mesh screen for recovery of fibre (recovered fibre is returned to hydrapulper and which ultimately increases waste paper recovery by 3%) . The filtrate from hill screen is fed into primary clarifier for removal of suspended fibres, fines etc to the maximum possible extent. The major part of overflow (~1825 m^3/d) is reused into pulp mill and resh (625 m^3/d) is treated through activated sludge process. The required level of dissolved oxygen is maintained in aeration tank using fixed mechanical aerators (6x25HP) as well as diffused aeration system. The overflow of aeration tank carrying active biomass is clarified through two numbers of secondary clarifiers. The part of underflow of secondary clarifiers is recycled to maintain desired level of MLSS (2000- 2500 mg/l) in aeration tank. The excess underflow of secondary and primary clarifiers is taken to filter press to increase the dry solids of ETP sludge for further disposal to board mill or to be used as fuel in boiler. The essential nutrients like nitrogen and phosphorus are provided by adding urea and DAP to promote the bacterial growth in order to achieve the designed performance efficiency of activated sludge process. The part of secondary clarifier overflow (~200 m^3) is passed through filter press for removal of fine particulate matter and the filtrate of filter press is reused at high pressure shower after mixing with fresh water. The balance 425 m^3 is mixed with primary clarifier overflow for further reuse into process. The mill is recycling entire quantity of waste water into mill.

CHARACTERISTICS OF BACK WATER

The overflow of back water tanks from pulp mill and paper machines are going to equalisation tank at ETP through a drain. The characteristic of combined waste water is indicated in **Table 4.15**

Table 4.15 Characteristics of Backwater in Mill C

Particular	Equalisation tank inlet
pH	6.0
Total solids, mg/l	6744
Suspended solids, mg/l	1221
Dissolved solid, mg/l	5523
COD total , mg/l	2331
COD soluble, mg/l	1642
Volume, m^3	2500

The performance of various units of effluent treatment system i.e. primary clarifier, secondary biological treatment system, and filter press were also assessed, as indicated in **Table 4.16 (a) – (d)** :

Table 4.16 (a) Performance of Primary Clarifier

Particular	PC inlet	PC outlet	Reduction %
pH	6.4	6.4	-
Total solids, mg/l	6805	5692	16.36
Suspended solids, mg/l	1138	366	67.83
Dissolved solids, mg/l	5667	5326	6.0
COD total, mg/l	2306	1632	29.23
COD soluble, mg/l	1718	1475	14.14
BOD total, mg/l	1330	1137	14.51
BOD soluble, mg/l	97	964	3.31

Table 4.16 (b) Performance of Secondary Biological Treatment System

Particular	PC outlet	SC outlet	Reduction %
pH	6.4	6.6	-
Total solids, mg/l	5692	2668	53.13
Suspended solids, mg/l	366	146	60.10
Dissolved solid, mg/l	5326	2522	52.65
COD total , mg/l	1632	251	84.62
COD soluble, mg/l	1475	217	85.29
BOD total, mg/l	1137	58	94.90
BOD soluble, mg/l	997	26	97.39

A part of secondary clarifier overflow (~200m^3) is passed through filter press for further removal of fine suspended & colloidal matter to make it reusable alongwith fresh water at high pressure shower.

Table 4.16 (c) Characteristics of Treated Effluent After Filter Press

Particular	Filter Press inlet	Filter press outlet	Reduction %
pH	6.6	6.6	-
Total solids, mg/l	2668	2544	4.65
Suspended solids, mg/l	146	60	58.90
Dissolved solids, mg/l	2522	2484	1.51

Table 4.16 (d) Characteristics of Combined Effluent of Primary & Secondary Clarifier Overflow Reused into Process.

Particular	ETP back water
pH	6.8
Total solids, mg/l	3682
Suspended solids, mg/l	167
Dissolved solid, mg/l	3515
COD total , mg/l	722
COD soluble, mg/l	570
BOD total, mg/l	357
BOD soluble, mg/l	243
Turbidity, NTU	263
Chloride, mg/l	213
Sulphate, mg/l	1150
Colour, PCU	79

OBSERVATIONS:

- The mill is using 100% Recycled fibre (RCF) & presently producing around 100 TPD of Kraft Paper of different BF using two paper machines depending on the market demand.
- The mill has cogeneration unit of ~ 6 MW turbines to meet the electric requirement of paper mill and steel plant belonging to same group.
- The most of the unit operation is completed with back water & treated effluent for which the mill has recently added filter press to get the desired quality of treated effluent

suitable for reuse after mixing with fresh water in high pressure showers at paper machines.

- The fresh water is used only in high pressure shower at paper machines, boiler and make up in cooling tower and it varies from 650 to 700 m^3 /d.
- The mill has upgraded the facility for treatment of back water/waste water suitable for reuse into process.
- The major part of primary clarifier overflow ~1800m^3/d out of 2425 m^3/d after mixing with part of secondary clarifier overflow ~425 m^3/d is reused in to process.
- The mill has recently installed filter press (Plate & frame) for removal of suspended and colloidal matter from treated effluent (after secondary clarifier) for further reuse after mixing with fresh water in high pressure showers at paper machines.
- The performance of effluent treatment plant has been found satisfactory with respect to COD, BOD, and TSS reduction.
- The quantity of fresh water used is around equivalent to the loss of water in terms of back water, steam losses, vapour etc.
- The mill has made remarkable efforts in recycling of back water particularly ETP treated water is completely reused in mill operation. The secondary clarifier overflow (~ 35%) after passing through filter paper is used in High Pressure Shower along with fresh water.
- The utility service area is the major area which consume about (~ 64%) fresh water followed by high pressure showers at paper machine (~ 18%).
- No fresh water is used for operation of pulp mill. All the operation of pulp mill are on back water either from pulp mill/paper machine back water tanks or water from back water recycling tank at ETP.

- The mill uses ~200 m^3/d fresh water after mixing with treated effluent (~200 m3) in high pressure showers at the paper machines.
- The mill has stopped the use of low pressure showers.
- The mill is not discharging any quantity of effluent outside the mill campus.
- The mill has made considerable effort in improving the process as well as ETP facility for reducing the fresh water consumption to the level equivalent to losses of water in paper making process.
- The mill has already upgraded ETP for treatment of back water for its reuse in to the process & now the mill has achieved zero effluent discharge.
- The back water generated is reused completely after treatment.
- The mill has started segregation & collection of back water in closed loop i.e. pulp mill & paper machine for further cascading its reuse.
- On the basis of findings of above studies CPPRI is of the opinion that if the mill operates on its full installed capacity (~150 t/d), the fresh water requirement will be almost same as presently used and even there are chances for reducing fresh water consumption due to increase in evaporation of water through dryers.

(d) Case Study IV : Mill D RCF Based Kraft Paper Mill Producing Unbleached Grade of Paper)

The mill D is a RCF based kraft paper mill producing unbleached grade of paper with production capacity 80 tpd . The mill uses both indigenous & imported waste paper for producing Kraft paper of 100- 150 GSM . The mill is reported to be operating on ZLD for last 2 yaers with average fresh water consumption of the mill is 1.9 m^3 / t_{paper}

Manufacturing Process

The paper manufacturing process includes processing of waste paper through **Hydra Pulper** to produce pulp. The waste paper pulp is further screened & cleaned through **HD cleaner, Turbo Separator, Centricleaners & Slotted Screen**. The pulp consistency in Head Box is maintained as per required GSM. The general layout of manufacturing process for paper making is indicated in **Fig. 4.7** .

Almost all of the process operations are being carried out with back water after treatment for removal of suspended impurities through Rifflers and Sedicell and fresh water is used as make up water only. The mill has two Bore Wells equipped with flow meter and running hour meter. At a time one is in operation and one kept as stand by. Regular log book is being maintained by the mill for daily fresh water consumption including operating hours. The average fresh water consumption is around **150 m^3/day** i.e. **1.9 m^3/t $_{paper}$**, and the section wise water consumption is given in **Table 4.17** :

Table 4.17 Fresh Water Consumption in Mill D

Unit	Fresh Water Consumption, m^3/day
Pulp Mill	Nil (back water is used)
Paper Machine	80
Glands Cooling	Nil (back water is used)
Vacuum Pump Sealing	
Boiler Feed water	35
Chemical Preparation	25
Domestic Use	10
Total @ 80 TPD Kraft Paper production	**150**
m^3/t $_{Paper}$	**1.9**

PRESENT PRACTICE OF BACK WATER TREATMENT & ITS REUSE INTO PROCESS:

The excess back water from pulp mill & paper machine is first passed through **Riffler** for removal of heavy particles (dust, sand etc.) and collected in **Primary Tank**. From primary tank, back water is sent to **Sedicell based on dissolved air floatation (DAF)** for fibre recovery using coagulant & flocculent. Sedicell outlet is collected in Back water **Storage Tank**. From Storage Tank, clarified back water is reused for vacuum pump sealing & cooling, in paper machine low pressure showers, for consistency regulation, H.D. Dilution, Turbo dilution in different operations etc. as per requirement. The mill has installed flow meter at back water reuse line. The fibres recovered from Sedicell are reused in pulp mill which results in enhancing the overall fibre recovery. No trace of waste water being discharged outside the premises of the mill, as observed at the time of mill visits. The general layout of back water treatment system is indicated below in **Fig. 4.8**

Methodology for Evaluation of ZLD Feasibility

- Monitoring of Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) level in back water samples collected at different time intervals from various sources of the mill.
- Water balance study with respect to intake & losses during paper making.
- Material balance study with respect to inputs & outputs during paper making.
- Lab study for estimation of TDS, COD & BOD generation per day in back water due to raw material (waste paper) used by the mill.
- Evaluation of TDS, COD & BOD loss due to carryover with finished paper & solid wastes w.r.t. their generation due to raw material (waste paper) used by the mill.

Monitoring of TDS, COD and BOD Level Accumulated in Back Water Samples Collected from Different Sources:

The level of TDS, COD and BOD in back water sample collected from different sources of the mill at different time intervals are summarized in **Table 4.18** below and also depicted in **Fig.- 4.9 (a) – (c)** :

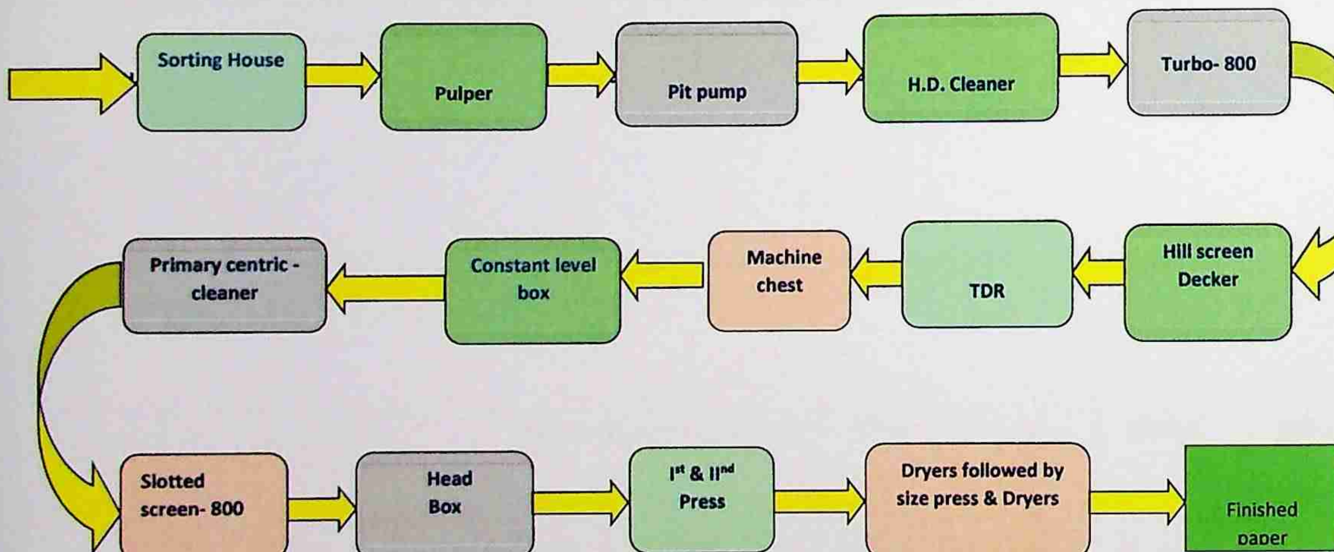


Fig 4.7 Manufacturing Process in Mill D

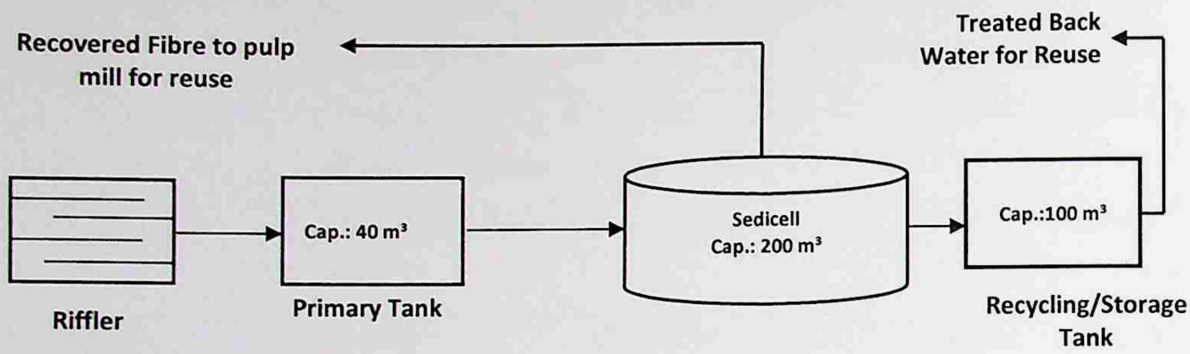


Fig. 4. 8 : Layout of Existing back water treatment system at Krishnanchal Pulp & Papers Private Limited, Muzaffarnagar

.

Table 4.18 Characteristics of back water samples collected at different time intervals

S. No.	Period	Back Water Source	TSS, mg/l	TDS, mg/l	COD, mg/l	BOD, mg/l
1.	1st Sampling (July, 2019)	Paper Machine Wire Tray	3,424	36,195	31,754	22,150
		Primary Tank (Sedicell Inlet)	3,476	34,748	33,461	23,050
		Sedicell outlet (Storage tank)	615	33,664	32,778	21,850
2.	2nd Sampling (August, 2019)	Paper Machine Wire Tray	3,445	35,316	30,848	21,500
		Primary Tank (Sedicell Inlet)	3,459	34,922	32,424	22,300
		Sedicell outlet (Storage tank)	628	33,452	31,788	21,150
3.	3rd Sampling	Paper Machine Wire Tray	4,133	36,825	32,652	21,400

	(August 2019)	Equalization Tank (Sedicell Inlet)	3,865	35,412	31,865	21,586
		Treated Back Water(PC Outlet)	635	34,825	32,100	21,758
Average Characteristics		**Paper Machine Wire Tray**	**3,667**	**36,112**	**31,751**	**21,683**
		Primary Tank (Sedicell Inlet)	**3,600**	**35,027**	**32,583**	**22,312**
		Sedicell outlet (Storage tank)	**626**	**33,980**	**32,222**	**21,586**

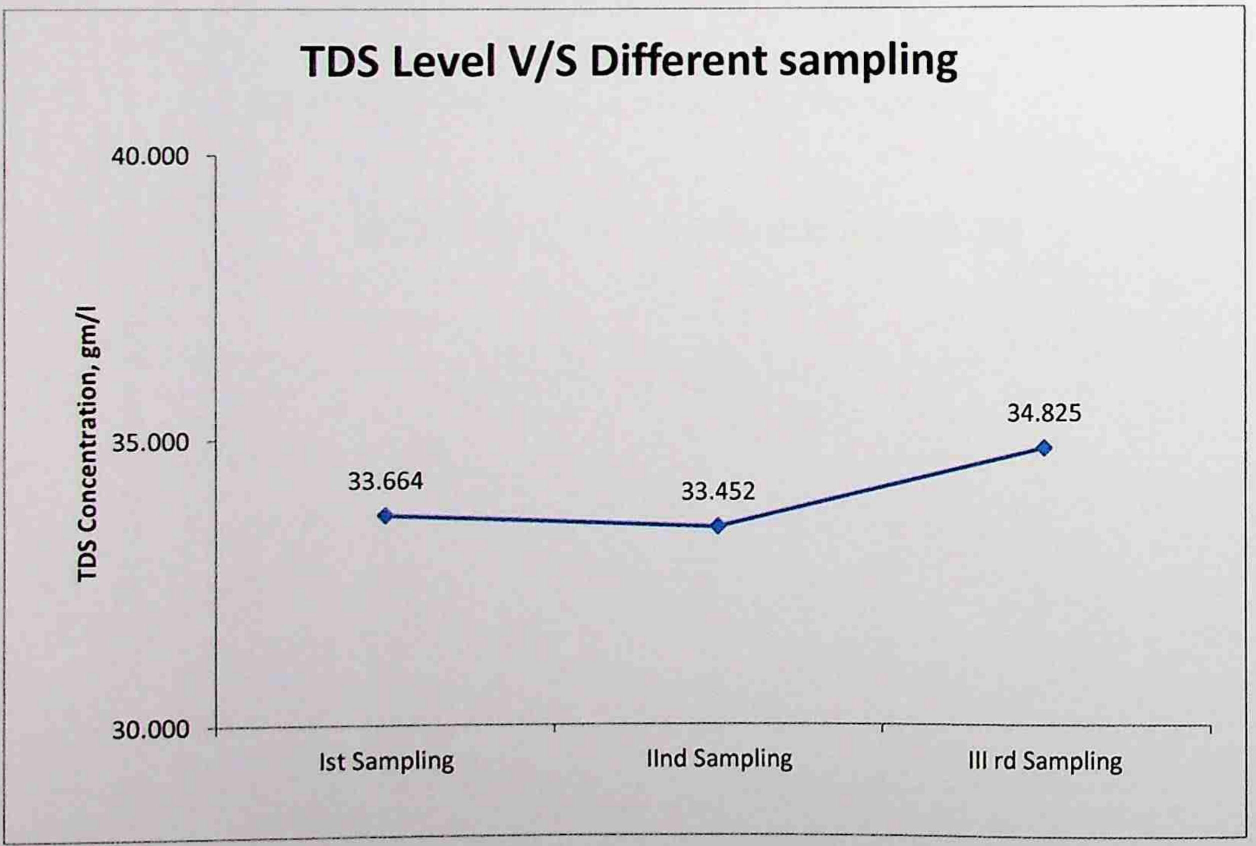


Fig.-4.9 (a) : TDS trend in Back water (Storage tank)

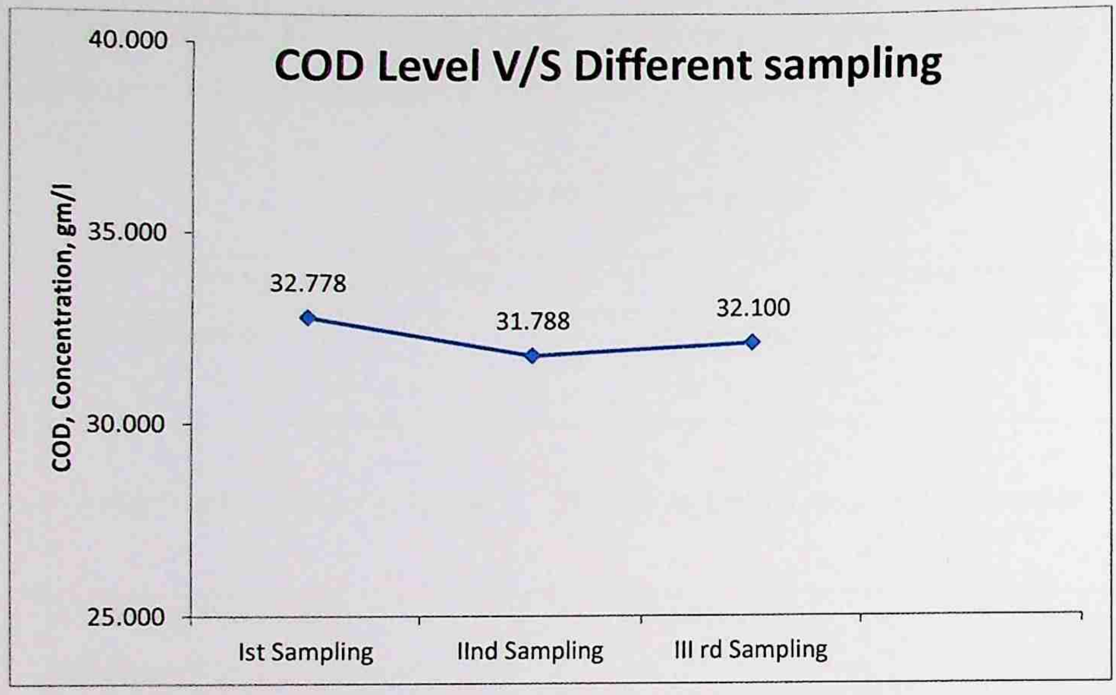


Fig.-4.9(b) : COD trend in Back water (Storage tank)

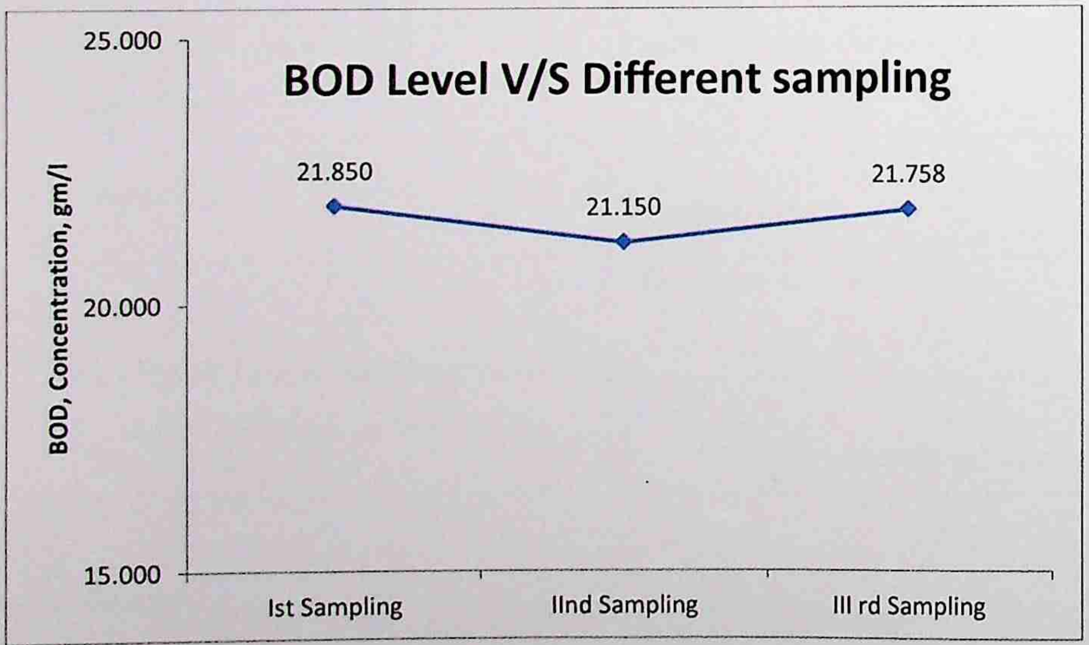


Fig.-4.9 (c) : BOD trend in Back water (Storage tank)

Water Balance

As indicated below in **Table -4.19** the total water intake including moisture in raw material (waste paper) is **157 m^3/day** for 80 TPD kraft paper production which is used as make up water to compensate water losses during paper making. Water losses include evaporation from paper machine pre & post dryer sections, steam loss, water carryover with finished paper & solid rejects, domestic loss etc.

Table-4.19 : Water balance

Water Intake, m^3/day		Water Loss, m^3/day	
Paper Machine	**80**	Evaporation from Pre-dryer section	**71**
Boiler Feed as Make Up Water	**35**	Evaporation from post-dryer section	**24**
Chemical Preparation (Surface Sizing of paper and treatment of back water)	**25**	Steam Loss	**35**
		Carry over with solid rejects	**5**
Moisture with raw material (Waste Paper)	*7*	Carry over with finished paper	**5**
Domestic Use	*10*	Domestic Loss	**10**
Total Water Intake including moisture in raw material, m^3/day= 157		Miscellaneous Loss	**7**
		Total Water loss, m^3/day = 157	

. **Material Balance**

The major inputs & outputs involved in manufacturing of **80 TPD** kraft paper are summarized as under in **Table- 4.20** and also depicted in **Fig.- 4.10 :**

Table-4.20 : Material Balance

Inputs, tonnes/day		Outputs, tonnes/day	
Waste Paper - On as such basis (Moisture:8.5 % w/w) - On oven dried basis	83 **76**	**Finished Paper** - On as such basis (Moisture: 6.29 % w/w) - On oven dried Basis	80 **75**
Dissolved Solids (Due to carryover of back water with paper sheet going to dryer section after press part)	**3.06**	**Solid Rejects** (Sand, plastic, pins etc.)	**3.37**
Starch (Surface Sizing Chemical etc.)	**2.5**	**Solids** (Dissolved in back water generated)	**3.19**
Total	**81.56**	**Total**	**81.56**

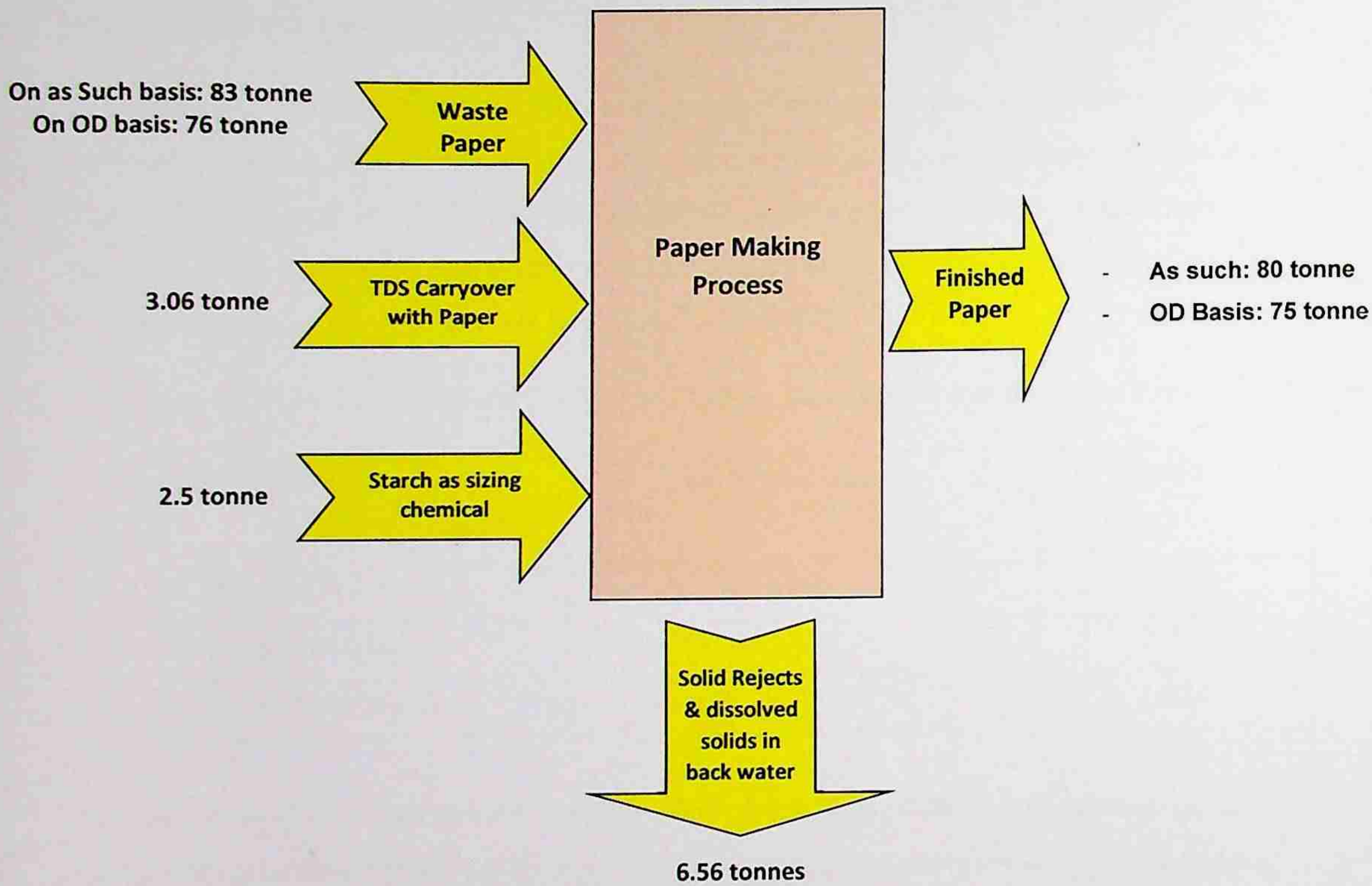


Fig 4.10 Material Balance in Paper Making in Mill

Estimation of TDS, COD & BOD generation per day in back water due to raw material (waste paper) used by the mill

As indicated earlier, on an average **76 tonnes per day indigenous/imported waste paper on oven dried basis** is used as raw material and a little amount of chemicals (Starch, Flocculent, Colour etc.) are used for kraft paper manufacturing as per requirement of the product quality. An attempt has been made in CPPRI laboratory to estimate the generation of TDS, COD & BOD in back water due to waste paper as given in **Table 4.21 :**

Table 4.21 Generation of TDS, COD & BOD in Back Water due to Waste Paper

Particulars	Kg/tonne waste paper	kg/day
TDS generation	41.97	3,190
COD generation	37.86	2,877
BOD generation	25.32	1,924

The estimation of the concentrations of TDS, COD & BOD at which their generation per day due to process of waste paper equals to their loss per day due to carryover with finished paper is calculated as given in **Table 4.22 (a) – (c) :**

- Amount of back water with paper sheet after press part: 82.0 m^3
- Amount of back water with solid rejects: 5.0 m^3
- Total amount of back water with paper sheet + solid rejects: 87.0 m^3

Particulars	Estimated Pollution Load Generation, kg/day	Estimated Concentration, g/l
TDS	3,190	36.67
COD	2,877	33.07
BOD	1,924	22.12

Evaluation of TDS, COD & BOD Losses Due to Carryover with Finished Paper & Solid Wastes w.r.t. their Generation Due to Raw Material (Waste Paper) Used by the Mill

4.22(a) Evaluation of TDS generation & its loss

Particulars	**Value**
Back water carryover with paper sheet after press part	82 m^3
Back water carryover with solid wastes	5 m^3
TDS carry over with finished paper, kg/day	2,961
TDS carry over with solid wastes, kg/day	181
Total TDS loss (calculated), kg/day	***3,142***
Estimated TDS generation, kg/day	***3,190***

Table 4.22(b) Evaluation of COD Generation & Its Loss

Particulars	**value**
Back water carryover with paper sheet after press part	82.0 m^3
Back water carryover with solid wastes	5 m^3
COD carry over with finished paper, kg/day	2,604
COD carry over with solid wastes, kg/day	159
Total COD loss (calculated), kg/day	***2,763***

Estimated COD generation, kg/day	***2,877***

Table 4.22 (c) Evaluation of BOD Generation & Its Loss

Particulars	**value**
Back water carryover with paper sheet after press part	82.0 m^3
Back water carryover with solid wastes	5 m^3 @
BOD carry over with finished paper, kg/day	1,778
BOD carry over with solid wastes, kg/day	108
Total BOD loss (calculated), kg/day	***1,886***
Estimated BOD generation, kg/day	***1,924***

The results reported above indicate that the generation of TDS, COD & BOD from waste paper i.e. **i.e. 3,190 kg/day, 2,877 kg/day & 1,924 kg/day** respectively estimated in lab is almost equal to their losses due to carryover with finished paper & solid wastes i.e. **3,142 kg/day, 2,763 kg/day & 1,886 kg/day** respectively calculated at the concentration of TDS, COD & BOD analysed in back water samples

OBSERVATIONS

- The mill is manufacturing **80 TPD kraft paper** from waste paper by operating on zero liquid discharge (ZLD) since May, 2018.
- The entire quantity of back water after treatment through Sedicell is reused into process.

- The fresh water is used as makeup water only (**1.9 m^3/tonne $_{paper}$**) to compensate water losses during paper making process.

- The fresh water used as make up water (**150 m^3/day**) is used consumed in high pressure showers of paper machine, steam boiler and chemical preparation.

- The mill has an adequate facility for treatment of back water for removal of suspended/settled impurities to make it suitable for reuse into process.

- The existing back water treatment system consisting Primary Tank (40 m^3), Sedicell (200 m^3) and Back Water Recycling Tank (100 m^3) is adequate to treat even more than the present back water volume generated from 80 TPD kraft paper.

- No traces of waste water being discharged was observed at the time of mill visits.

- The average concentration of TDS, COD & BOD i.e. **36.11 gpl, 31.75 gpl & 21.68 gpl** respectively as analyzed in back water sample collected during mill visits has been found to be in close proximity to the concentration of TDS, COD & BOD i.e. **36.67 gpl, 33.17 gpl & 22.12 gpl** respectively estimated in lab study which clearly supports mill's claim of operation on zero liquid discharge (ZLD).

- The carryover (loss) of TDS, COD & BOD with finished paper & solid wastes i.e. **3142 kg/day, 2763 kg/day & 1886 kg/day** respectively has been found almost equal to the generation of these parameters from waste paper estimated in lab study **i.e. 3190 kg/day, 2877 kg/day & 1924 kg/day** respectively which further validates Mill operation on ZLD

- The mill has installed online camera facing backwater treatment system and its reuse line.

Chapter 5

Technological Intervention to Achieve ZLD

Chapter 5

Technological Intervention to Achieve ZLD

In context of issues related to foul odor in the environment as well as in paper products produced by Pulp & Paper Mills operating on ZLD studies were initiated for appropriate technological intervention to address these issues which are summarized as under :

5.1 Incorporation of Anaerobic Treatment in Back Water Loop of RCF based Kraft Paper Mill Operating on ZLD

With the studies conducted by CPPRI it was observed that due to build up of TDS , COD , BOD due to operating of mills on ZLD there has been adverse impact on machine runnability leading to frequent break down, low wire and felt life, as well as foul odor issues related to working environment and paper product .

Lab studies indicated good biodegradability potential in back water of RCF based Kraft Paper Mills operating on ZLD (70-80%) . In this perspective a joint synergetic effort was undertaken by CPPRI , Paques India, and a150 tpd RCF based Kraft Paper Mill operating on ZLD to incorporate biomethanation plant in the back water circuit to reduce the COD & BOD level

5,2 Paques India's BIOPAQ® ICX Technology – Mechanism

BIOPAQ® IC reactor is a new generation dynamic reactor recently introduced to treat wide range of organic pollutants, i.e. from 1,000 to 20,000 mg COD/l. The BIOPAQ® ICX Reactor **(Fig.5.1)**, was recently commissioned at this selected RCF based kraft paper mill which was incorporated as a pre -treatment step before conventional aerobic treatment for handling the back water of the paper mill. The anaerobic reactor is designed to biologically convert organic pollutants (measured as COD) present in the wastewater into biogas. The major merits associated with BIOPAQ®ICX reactor are:

- Reduction of VFA in water loop to ensure odour free paper production.
- Co-geneartion 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 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 acidification process occurs partly in the pre-treatment upstream of the anaerobic reactor (e.g. buffer/acidification tank) as well as inside the anaerobic reactor. The acidification which takes place upstream of the anaerobic reactor is called "pre-acidification". In most cases a certain degree of pre-acidification is desired because it enhances the performance of the anaerobic reactor and the biomass quality inside the anaerobic reactor.

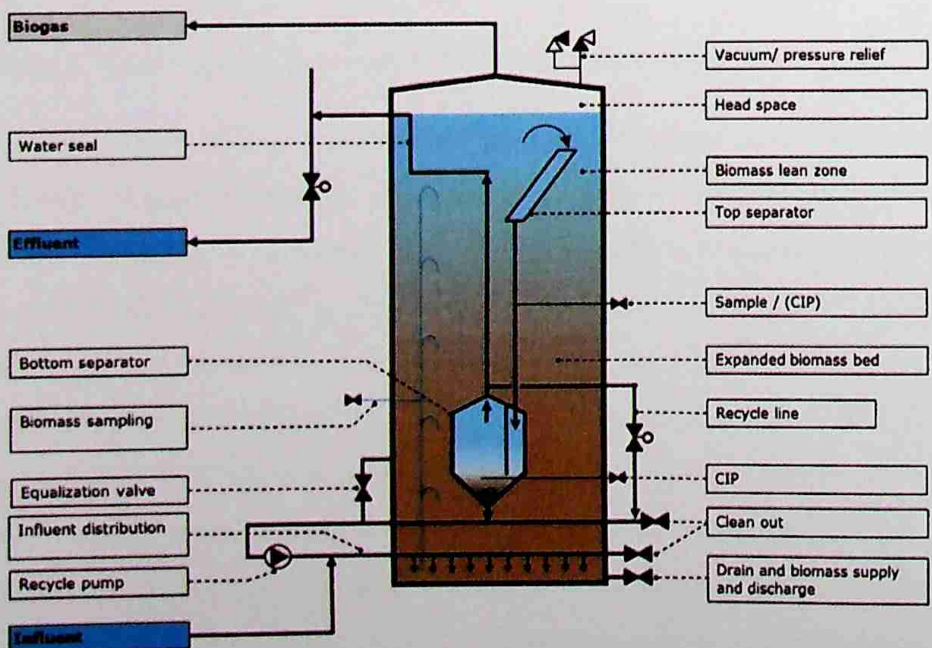


Fig 5.1 Schematic Diagram of BIOPAQ® ICX

In the reactor the anaerobic micro-organisms convert the COD present in the pre-acidified wastewater into methane (CH_4) and carbon dioxide (CO_2). The generated biogas is collected in the headspace of the reactor and subsequently transported to a gas buffer or other gas processing unit. The treated wastewater is separated from the biomass in the separators and leaves the reactor with a significant reduction in its COD concentration.

Besides the formation of biogas from COD, sulphurous compounds (sulphate, sulphite, thiosulphate and sulphur) are converted into hydrogen sulphide (HS^-) by sulphate reducing bacteria, which leads to the presence of H_2S in the biogas. This reaction is unwanted because it consumes COD, which cannot be used for methane production and the formed H_2S is toxic, corrosive and odorous; this reaction however cannot be avoided.

The performance of the reactor depends on several parameters of which the major one is as under:

- The quantity and the quality of the biomass in the reactor.
- The composition of the wastewater to be treated (COD composition, presence of toxic components).
- The operation conditions of the reactor (e.g., Temperature, pH, recycle flow rate etc.).
- The absence/presence of nutrients (macro and micronutrients).
- The performance of the pre-treatment.

5.3 Closed Loop System at the Selected RCF based Kraft Paper Mill

The closed water loop established at the RCF based kraft paper mill is indicated in **Fig 5.2** The fresh water is mainly added on paper machines make up water to compensate the water loss due to evaporation in paper machine. The back water from paper machine is collected in a collection tank followed by fibre recovery in sedicell. The sedicell outlet is sent to conditioning tank / buffer tank where macro / micronutrients required for growth of anaerobic microbes are added and pH is regulated. This is followed by anaerobic treatment through Biopaq® ICX reactor where the anaerobic microbes convert the biologically degradable organic matter into biogas. The anaerobically treated backwater is post treated anaerobically through aeration tank and followed by secondary clarifier to arrest the loss of biomass. The secondary clarifier overflow is reused in stock preparation thus closing the water loop. The DAF sludge & Secondary Clarifier Sludge is dewatered in screw press and sold to contractors

5.4 Commissioning of Bioreactor

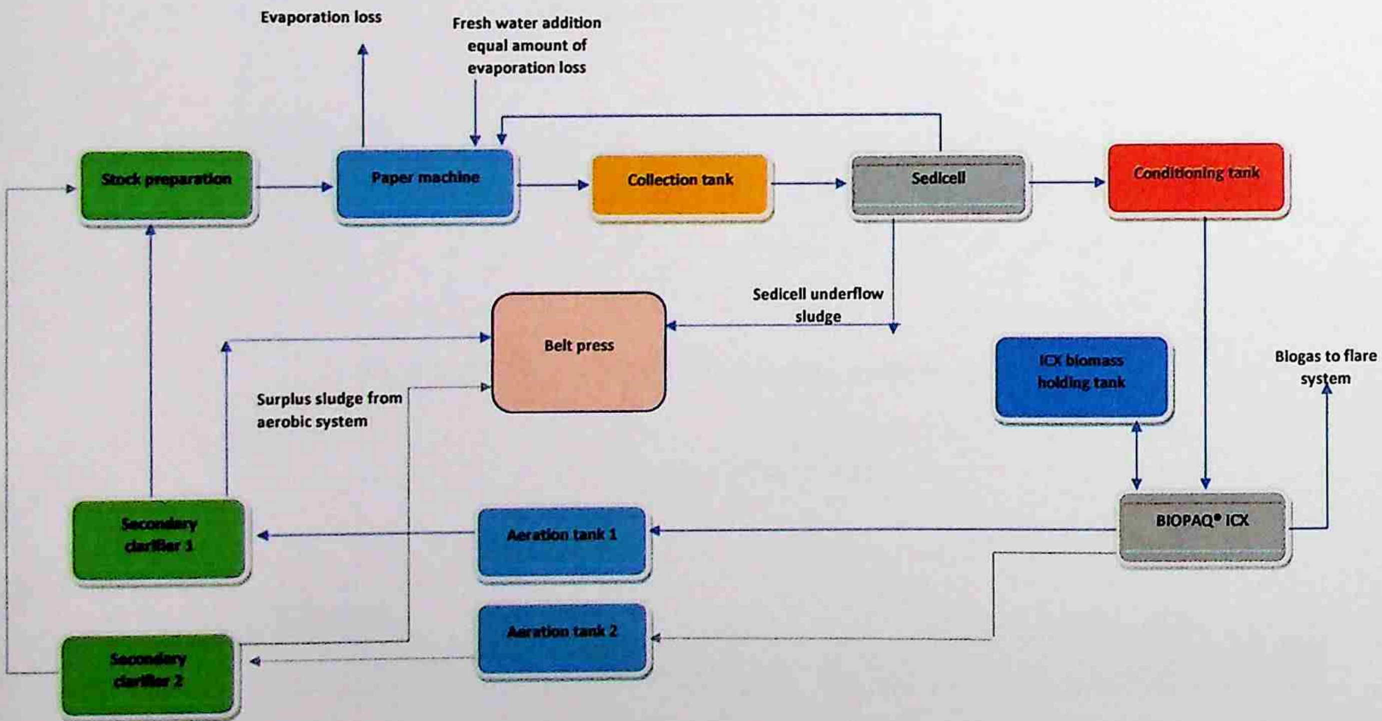
Commissioning of the ETP kick started on July 2020 with BIOPAQ® ICX reactor and the plant remarkably stabilized within 2 weeks. After implementing BIOPAQ® ICX system the mill has been benefited on following counts:

- Due to adequate biological treatment system the mill can now recycle 100% secondary clarifier water back into the process therefore, additional fresh water is not required for paper making
- The freshwater requirement is now only 1 to 1.5 m^3 / t paper which is added as make up water to compensate water evaporated in evaporation section during paper making process
- The Odour issue in paper has been resolved due to significant reduction in COD & VFA in the water loop after treatment through Paques BIOPAQ® ICX reactor

Advantage of BIOPAQ® ICX reactor in treating the backwater in the closed loop and reducing Calcium, SCOD, VFA, TDS etc as well as cogeneration of biogas is summarized in **Table 5.1**

Table 5.1: Machine Back Water Characteristics Comparison

S. No	Parameters	Before BIOPAQ® ICX commissioning	After BIOPAQ® ICX commissioning
1	pH	5.56	6.5 - 7.2
2	TSS (mg/l)	800	< 300
3	TDS (mg/l)	24400	< 9000
4	Calcium (mg/l)	5130	< 500
5	VFA (meq/l)	300	< 30
6	Paper odour	Yes	No
7	SCOD (mg/l)	57700	< 5000
8	Biogas generation (m^3/d)	0	2000 - 2500


Evaporation loss
Fresh water addition equal amount of evaporation loss
Stock preparation
Paper machine
Collection tank
Sedicell
Conditioning tank
Sedicell underflow sludge
Belt press
Surplus sludge from aerobic system
ICX biomass holding tank
Biogas to flare system
BIOPAQ® ICX
Secondary clarifier 1
Aeration tank 1
Aeration tank 2
Secondary clarifier 2

5.5 Performance Summary of BIOPAQ® ICX reactor

The above table indicates the efficiency and suitability of the BIOPAQ® ICX reactor in wastewater treatment to enable a RCF based Kraft Paper Mill to operate in a closed loop / ZLD as well as produce odour free paper. After Bio methanation commissioning VFA and SCOD in the water loop has reduced by over 10 times i.e., up to 20 meq/l and 5500 mg/l **(Fig 5.3)** respectively. Similarly, as indicated in **Fig 5.4** VFA has been found to be in range of just 20 to 30 meq/l after treatment which helps in reducing Odour issue. The overall performance efficiency of Biopaq® ICX Reactor summarised in **Fig 5.5**

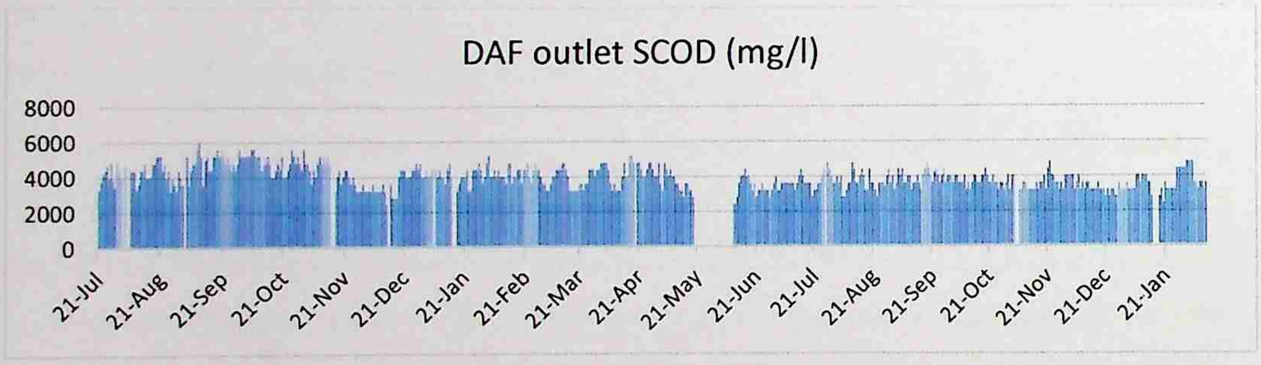


Fig 5.3 DAF outlet SCOD after Bio methanation

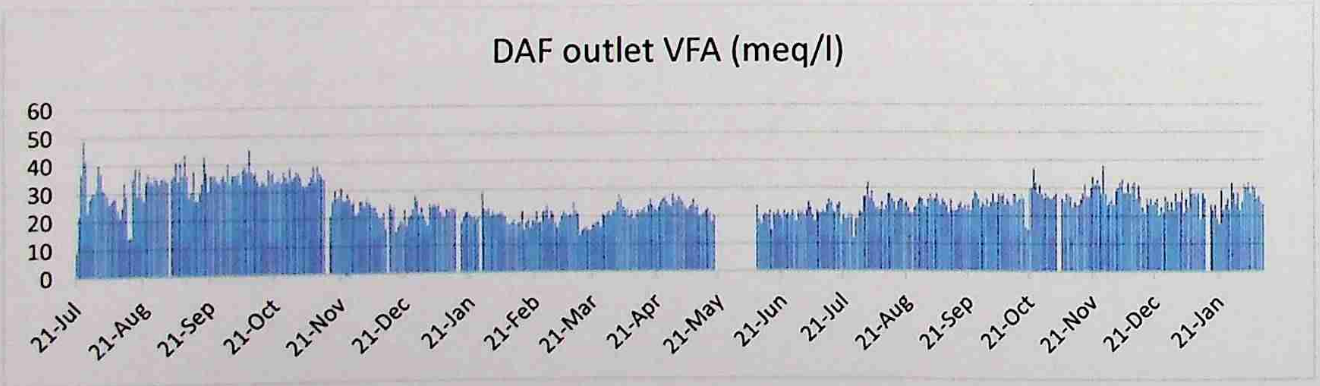


Fig 5.4 DAF outlet VFA after Bio methanation

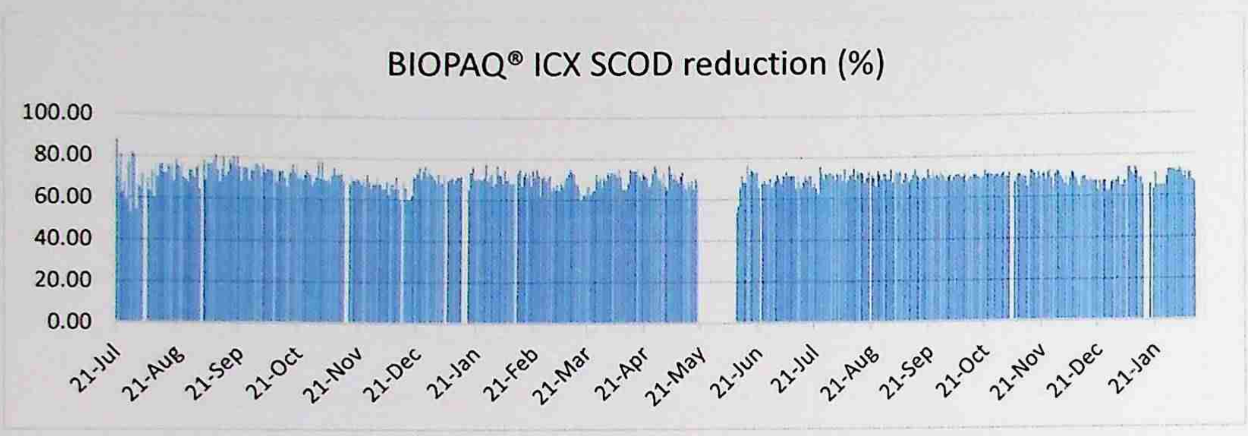


Fig 5.5 ICX SCOD efficiency

Elimination / Control of Odour in Paper

Odour in paper which was the major issue before this RCF based kraft paper mills operating on ZLD has been successfully addressed through BIOPAQ® ICX reactor. The major factors for odour in the paper are uncontrolled Volatile Fatty Acids (VFA) and Sulphides. These two organics and inorganics creates a foul smell due to increase build up in concentration when the back water is recycled several times in closed loop. The combination of adequate anaerobic and aerobic treatment like the present case study of offers is a techno-econmically feasible solution to this problem and thus facilitate production of odour free paper along with complete recycling and reuse of treated effluent.The kraft paper from this RCF based kraft paper mill operating on ZLD / closed loop has also been tested / certified as odour free & suitable for food grade by renowned testing agency, SGS Laboratories. **(Fig 5.6)**

SGS

TEST REPORT

Report No. : TR:TX:1144040786	DATE : 27-Aug-20

AKSHERA PAPERS
S F NO 557 5 BHAVANISAGAR ROAD, PASUVAPALAYAM
Tamil Nadu, Erode-638451
IN
CONTACT PERSON : MR VASANTHKUMAR

THE FOLLOWING SAMPLE(S) WAS/WERE SUBMITTED AND IDENTIFIED BY/ON BEHALF OF THE CUSTOMER AS :

PRODUCT DESCRIPTION	PAPER KHAFT PAPER (180 GSM) SUBMITTED	
COLOUR	GREY	
COUNTRY OF DESTINATION	INDIA	
COUNTRY OF ORIGIN	INDIA	
SAMPLE RECD ON	18-Aug-2020	TESTING PERIOD : 24-Aug-20 - 27-Aug-20

TESTS	PASS	FAIL	REMARKS
ODOUR TESTING			REFER RESULT

Fig 5.6 Test Report on Odour in Paper Product from RCF based Paper Mills operating on ZLD

5.6 Chlorine dioxide Treatment for Odor Control

As indicated above majority of the recycled waste paper based mills producing unbleached variety of packaging graded paper are faced with an serious issue related to the foul odour.

Major Factors for Foul Odor

- Factors responsible for the problems are-
- Trend towards increased use of recycled waste paper/ fiber,
- Inherent additive used in Waste paper ,
- Alkaline/ neutral sizing
- water system closer resulting in reduced solid and liquid discharge

- Paper machine backwater loop in a ZLD mill also support significant growth of microbes due to persisting during the paper manufacturing, such as pH, elevated temperature, high nutrient levels make paper mill system a perfect breeding ground for microbial growth

- In other cases , extremely closed systems(ZLD), the back water is usually reused from a fiber recovery system (DAF , Sedicell etc) . The increase in backwater water temperature, decrease in the dissolved oxygen level in water & development of anaerobic conditions and subsequent problems such as growth of aerobic and anaerobic microbes resulting in the accumulation of VFA contributes to odor generation

General Odor Control Approach

Strategies of controlling odor / microbial growth include:

- Prevention of the contamination of stock and additives (treatment/ preservation of intake process/ fresh water and additives like starch, slurries of fillers, retention aids, sizing solutions and control of the residence time in the storage tanks, stagnant flow areas to prevent anaerobic microbes from growing and producing foul smelling compounds
- Introduction of Chemical products (biocides and dispersants) into the system to control and address the issues related to microbial growth and to reduce foul odour and other associated the harmful effects

However , conventional biocides used are found to have limited efficacy besides challenges some times in respect to the environmental compatibility and regulatory restrictions. Occasionally new bacterial species colonizing the system may recur requiring change in the biocide or increased dosage

Chlorine dioxide Treatment for Odor Control

Recently CPPRI – UNIDO have jointly carried out pilot scale trials on application of ClO_2 based treatment in back water of a RCF based Kraft Paper Mill operating on ZLD.

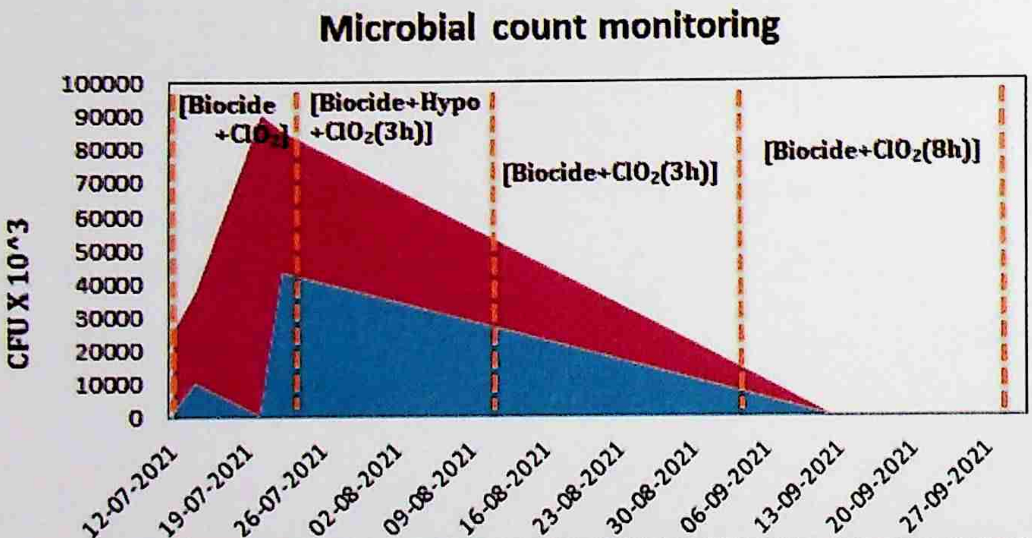
Mechanism

- Chlorine dioxide, known as broad-spectrum oxidising biocide could prove to be an effective alternative among various potential biocides (oxidising and non-oxidising) due to faster microbial killing rate, controlling foul odour and keeping processing equipment free of slime build ups.
- Chlorine dioxide is found to be extremely effective in destroying both EPS and the bacterial cells and have the ability to penetrate the polysaccharides barrier in the older and more aged bacteria which takes longer to kill due to clustering of newer generation around the older and a thicker slime which otherwise with non oxidising biocides, in common use may be a challenge.

Preliminary Results

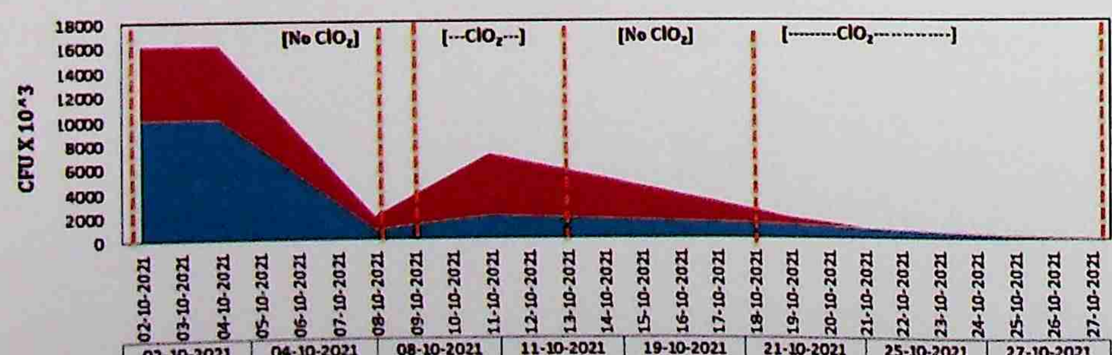
The preliminary results indicate :

- Reduction in microbial counts (anaerobes and aerobes) from a population range of 10^7 to less than 10^3/10^4, has been observed resulting in significant control of unpleasant smell/ odour and slime thus enhanced quality. (**Fig 5.1 & 5.2)**



	12-07-2021	14-07-2021	20-07-2021	22-07-2021	12-09-2021	18-09-2021	30-09-2021
Anaerobic count	24000	27000	90000	42000	37	49	57
Aerobic count	1500	10000	100	43000	60	25	75

Fig 5.1 Reduction in Microbial Count in Backwater due to Chlorine dioxide Treatment



	02-10-2021	04-10-2021	08-10-2021	11-10-2021	19-10-2021	21-10-2021	25-10-2021	27-10-2021
Anaerobic count	6000	6000	1000	5000	500		40	30
Aerobic count	10000	10000	800	1900	1100	800	180	50

Fig 5.2 Reduction in Microbial Count in Backwater due to Chlorine dioxide Treatment

- Significant reduction in volatile fatty acids (VFA) in the process water and in final paper product

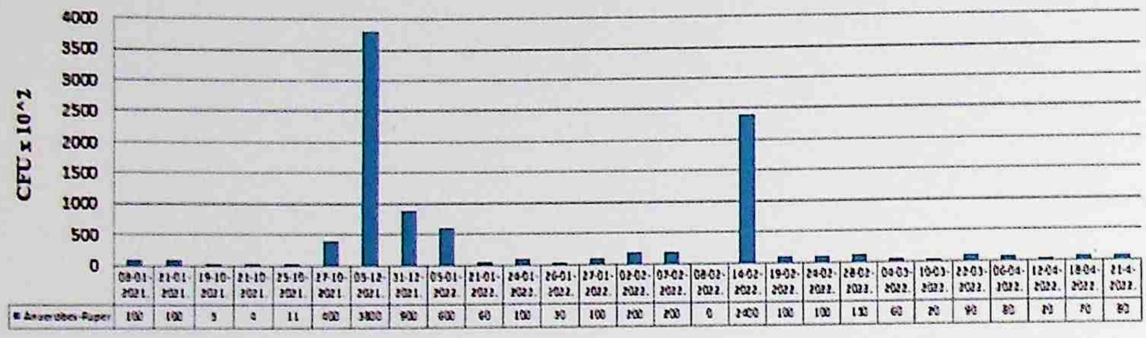


Fig 5.3 Reduction in Microbial Count in Paper Product due to Chlorine dioxide Treatment

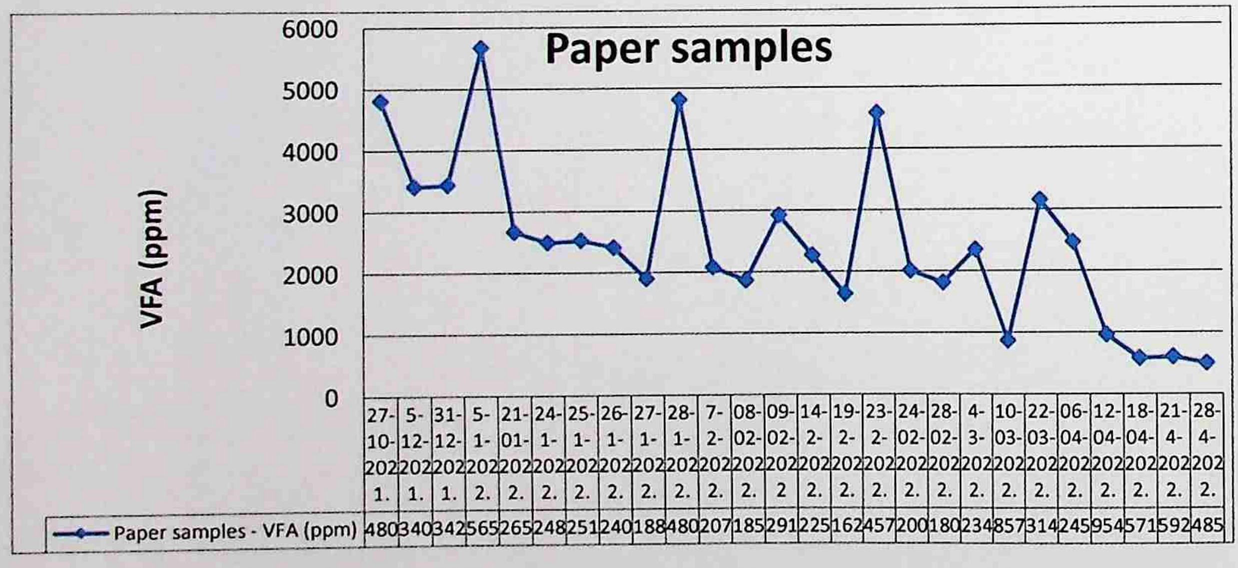


Fig 5.4 Reduction in VFA in Paper Product due to Chlorine dioxide Treatment

Chapter 6

Conclusions

Chapter 6

Conclusions

Based on the studies conducted, the protocol for evaluating feasibility / status of ZLD in a RCF based kraft paper mill is as under:

- Fresh Water Consumption benchmark for a mill operating on ZLD is :
- < 2.5 m^3 / t paper for kraft paper mills & newsprint paper mill without cogeneration power plant
- < 5 m^3 / t paper for kraft paper mills with cogeneration power boiler including cooling tower
- Removal of suspended solids through primary clarification / Sedicell is must for checking build up and microbial growth development in water circuit.
- Without ETP or appropriate treatment the mills have to compromise with strength properties of finished product, wire & felt life, machine down time, Odor problem in finish product etc. which needs to be critically documented.
- Critical monitoring of TDS , COD , BOD build up is necessary to check the impact on process operations and product quality.
- In such cases addition of imported waste paper furnish can help in improving / maintaining product quality
- Further studies are required with incorporation of advanced technologies with minimum impact of ZLD on machine productivity and product quality
- Based on the studies conducted , the average TDS , COD & BOD level in back water of a ZLD based Kraft Paper Mill operating on ZLD without ETP operation is :

Pollution load	Range
TDS, g/l	35 – 50

COD, g/l	24- 35
BOD, g/l	16 - 23

- Based on the studies conducted the average TDS , COD & BOD level in back water of a waste paper based Newsprint Paper Mill operating on ZLD without ETP operation is :

Pollution load	Range
TDS, g/l	6-8
COD, g/l	4-7
BOD, g/l	1.5-3.0

- The mills need to operate the conventional ETP equipped with tertiary treatment system for having less impact on product quality and machine runnability.

- Recently some mills operating on ZLD on CPPRI recommendations have incorporated biomethanation plant in the backwater loop which has resulted achieving optimum COD < 5000 mg/l resulting in elimination of odor in mill environment and paper as well as reduction in breakdown

- The mills operating on ZLD should also :

  - Maintain daily record / log book of raw material (waste paper) consumption , chemical consumption (process & ETP separately) , paper production , energy consumption (process & ETP separately)
  - Have maximum 2 borewell (1 in Operation & 1 Stand by).
  - Operational flowmeter with totalizer on borewell
  - Record daily fresh water consumption (initial reading & final reading) along with daily production in tpd in log book (in m3 / day and m3/ t paper) duly signed daily by authorized signatory / competent authority.

- Install appropriate flow meter / flow measuring device to monitor the volume of backwater generation
- Install a flow meter with totalizer on the recycling pipe line and the flowmeter should be connected to State / CPCB Server
- Install PTZ camera at Sedicell / back water storage tank from where the back water recycled , backwater recycling flow meter as well as at ETP (if available)
- The success of the case study of the RCF based kraft paper mill operating on ZLD in addressing the contentious issues related to ZLD operation specially odour in paper and paper products by incorporation of effluent treatment system comprising of anaerobic treatment and aerobic treatment in back water loop has set an example for other similar mills operating on ZLD / wishing to switch over to ZLD. The reduction / optimisation of pollution load specially TDS, Calcium, COD, VFA etc has helped the ZLD based RCF paper mills in overcoming the bottlenecks in ZLD operation like adverse impact on product quality, machine runnability, VFA and odour in paper and surrounding environment. The co-generation of biogas is an additional advantage along with water conservation and elimination of wastewater discharge.
- Incorporation of chlorine dioxide dosing into head box / paper machine Silo tank has shown encouraging results in terms of reduction in odor in paper and back water circulating in closed loop

Annexure

(Publications)

ISSN: 0379-5462

IPPTA: Quarterly Journal of Indian Pulp and Paper Technical Association
Vol. 30, E2, 2018, pp.63-68

Validation of Feasibility of Zero Liquid Discharge in a RCF based Kraft Paper Mill – A Case Study

Nitin Endlay, S. Mishra, Mohd Salim & B.P. Thapliyal

Central Pulp & Paper Research Institute, Saharanpur (U.P.), India

Abstract: *The implementation of Charter for Water Recycling and Pollution Prevention in Pulp and Paper industries of Ganga River Basin resulted in significant reduction in fresh water consumption of Pulp & Paper mills due to introduction of fresh water consumption norms. RCF based kraft paper mills in particular have significantly reduced their fresh water consumption and waste water discharge in accordance to charter norms of 10 and 6 m^3 / t paper respectively. The reduction in fresh water consumption due to reuse / recycle of back water results in significant increase in pollution load thus requiring exhaustive treatment facility up to tertiary treatment level to meet the norms. In this context, a few RCF based kraft paper mills have opted for Zero Liquid Discharge (ZLD) through complete recycling / reuse of back water and have discontinued their existing ETP operation. However, validation of the ZLD status is a major issue before the mills and regulatory authorities. The paper highlights a case study taken up by CPPRI to validate the ZLD status of a RCF based kraft paper mill.*

Key Words: Pulp and Paper Industry, Kraft Paper Mill, RCF

Introduction

With enforcement of stringent norms under **Charter for "Water Recycling & Pollution Prevention in Pulp and paper Industries in Ganga River Basin"** and likely revision of national norms on the same lines, most of the RCF based paper mills in Ganga River Basin have already made a lot of efforts on reducing fresh water consumption through process optimization increased reuse and recycling of treated effluent / back water and ETP upgradation.

The reduction in fresh water consumption through reuse / recycle of back water results in significant increase in pollution load thus requiring exhaustive treatment facility up to tertiary treatment level to treat the effluent. In this context some RCF based kraft paper mills instead of opting for ETP upgradation, have opted to go for Zero Liquid Discharge (ZLD) and have discontinued their ETP operation. The idea is to save O & M costs involved in ETP operation as well as avoid non compliance issues. However, it was difficult for the mills to prove their ZLD status as well as for the regulatory authorities to validate their ZLD status without any technical background.

In this context, CPPRI took up the initiative to carry out indepth studies for evaluating technical feasibility of ZLD status as claimed by the RCF based pulp and paper mills in a systematic and methodical manner. One of such study is summarized as under –

Case Study

The case study involves a RCF based kraft paper mill which has switched over to ZLD without any technology intervention, the profile of which is as under:

Production Capacity, tpd	90
End Product Produced	Kraft Paper
Source of Water	Ground water
Fresh Water Consumption, m^3 /day m^3 / t paper	140 1.56

Almost all of the process operations are being carried out with back water after removal of suspended fibres & impurities through Hill Screen, Sedicell, Vibro Screen, and Spray Filter. The fresh water is used as make up water only to compensate water lost during paper making. A break up of fresh water consumption by the mill is summarized in **Table – 1:**

Table 1: Fresh Water Consumption by the Selected RCF based Kraft Paper Mill

Unit	Fresh Water Consumption, m^3/day
Pulp Mill	Nil
Paper Machine	90
Cooling & sealing	Nil
RO Plant	35
Spray Filter (For Back Wash)	5
Domestic & Miscellaneous	10

Present Practice of Back Water Reuse & Recycle

The back water reuse & recycle system involves Riffler, Hill screen, Storage tank, Sedicell, Clear water tank, Vibro screen, Spray filter and Filter press (Plate & Frame Type). First, the excess back water from paper machine along with pulp mill back water (Total: ~ 2500 m^3/day) is sent via riffler to hill screen for fibre recovery. Hill screen filtrate is collected in storage tank. A part of back water from storage tank is reused in pulp mill and rest is sent to sedicell for further fibre recovery. Sedicell outlet is collected in Clear water tank. A part of clear water is reused for cooling & sealing and in low pressure showers at paper machine after passing through vibro screen and rest is used in high pressure showers at paper machine after passing through spray filter. Fresh water is used in edge cutting & high pressure showers at paper machine, in steam boiler and for miscellaneous use as make up water only to compensate water lost during paper making. Fiber recovered through hill screen & sedicell is reused in pulp mill and sedicell settled sludge is disposed off after dewatering through filter press (plate & frame type). The mill has discontinued the use of existing aeration tank and is using existing primary & secondary clarifiers as Storage tank & Clear water tank respectively. No traces of waste water being discharged outside the premises of the mill were observed at the time of visit. The details of back water reuse & recycling system are given in **Table-2** & layout in **Fig.-1.**

Table 2: Units of back water reuse & recycle system & their specifications

Units	Specification	Purpose
Hill Screen	3.5 m x 4.0 m x 4.0 m	Fibre recovery & filtration
Storage Tank	Capacity: 500 m^3	Uniform feeding to sedicell & pulp mill
Sedicell	Capacity: 250 m^3	Fibre recovery & Removal of settalable impurities
Clear Water Tank	Capacity: 400 m^3	Uniform feeding to spray filter, vibro screen & pulp mill
Vibro Screens	3 Nos.	Removal of suspended impurities
Spray Filter	Capacity: 50 m^3/hr	Removal of fines & colloidal particles
Filter Press (Plate & Frame Type)	52 plates	Dewatering of sedicell settled sludge

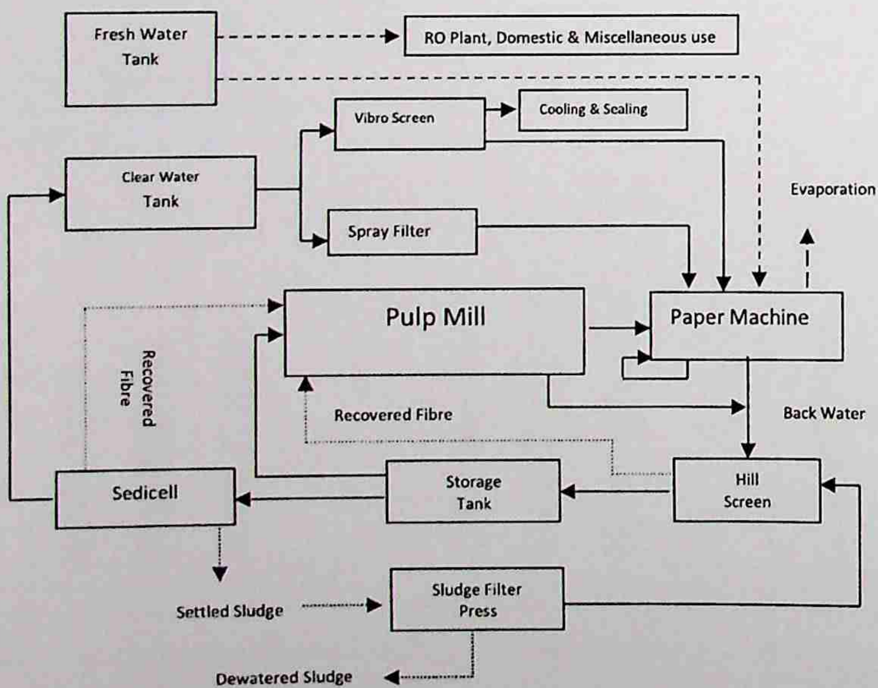


Fig.-1: The back water reuse & recycling system in the selected RCF based kraft paper mill

Verification of Zero Liquid Discharge (ZLD) Status

Feasibility study of Zero Liquid Discharge (ZLD) status as claimed by the mill has been carried out by

a) Monitoring of TDS, COD & BOD level in back water samples collected at different time intervals from various sources of the mill
b) Estimation of Water Intake v/s Water Loss
c) Material balance w.r.t. inputs & outputs
d) Estimation of the generation of TDS, COD & BOD per day in back water due to waste paper & chemicals/additives used by the mill
e) Estimation of the TDS, COD & BOD concentration in back water at which their generation equals to their loss
f) Evaluation of TDS, COD and BOD loss due to carryover with finished paper & solid rejects w.r.t. their generation due to waste paper & chemicals used by the mill

a) Monitoring of TDS, COD and BOD Level in Back Water Samples Collected at Different Time Intervals from Different Sources of the Mill

CPPRI monitored the TDS, COD and BOD level in paper machine back water & clear back water (sedicell outlet) collected from the mill at different time intervals. The analysis results are summarized in **Table-3** and trend of the level of TDS, COD & BOD at different time intervals is depicted in **Fig. -3** as under:

Table-3: Periodical Monitoring of Pollution Load in Back Water

S. No.	Period	Sources	TDS, mg/l	COD, mg/l	BOD, mg/l
1.	1st sampling	Paper Machine Back Water (Supernatant)	29778	26285	17905
		Clear Back Water	31183	26780	18477
2.	2nd sampling	Paper Machine Back Water (Supernatant)	31766	26851	19035
		Clear Back Water	32246	28006	20062
3.	3rd sampling	Paper Machine Back Water (Supernatant)	33824	24432	18626
		Clear Back Water	33242	24613	18498
4.	**Average characteristics of Paper Machine Back Water (Supernatant)**		**31789**	**25856**	**18522**
5.	**Average characteristics of Clear Back Water (After Sedicell)**		**32224**	**26466**	**19012**

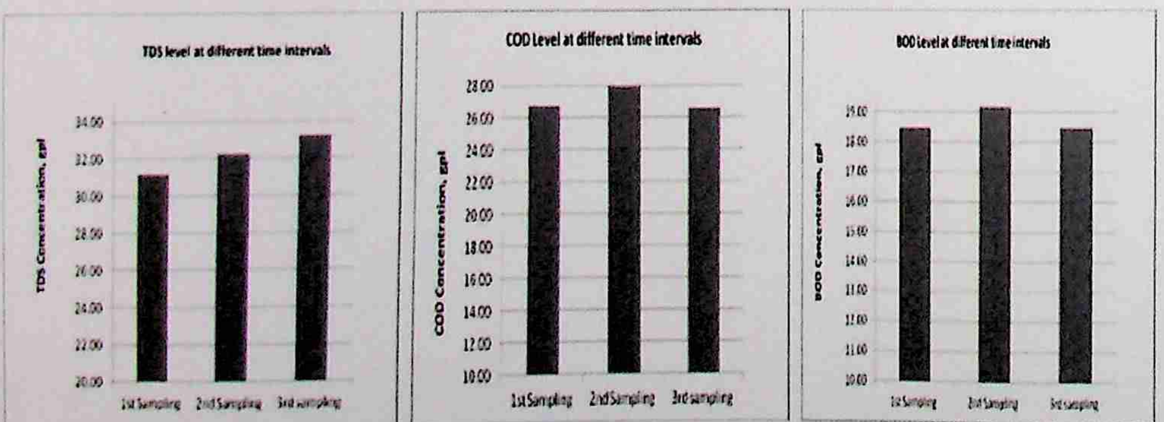


Fig.-3: Almost constant level of TDS, COD & BOD in clear back water collected at different time intervals

b) Estimation of Water Intake v/s Water Loss

Water balance studies were carried out to verify and justify the intake of fresh water consumption. The major water loss in the mill includes water loss due to evaporation in dryer section, steam loss and miscellaneous loss during paper making process, the volume of which is as under:

– The water loses as evaporation from dryer section 99 m^3/day (1.1 m^3/t_{paper}).
– The steam loss and other losses during paper making process i.e. 48 m^3/day (0.53 m^3/t_{paper})

The details of the water intake used as make up water to compensate water losses due to evaporation from paper machine dryer section, steam loss, carryover of back water with solid rejects etc is given in **Table-4:**

Table – 4: Estimation of Water Intake v/s Water Loss

Water Intake, m³/day		Water Loss, m³/day	
Paper machine	90	Evaporation from dryer section 〉 Inlet dryness: 45 % (w/w) 〉 Outlet dryness: 94.5 % (w/w)	99
RO plant*	35	Steam Loss (Condensate recovery = 85 %)	20
Moisture with waste paper**	7	Carry over with solid rejects	5
Spray filter (for back wash)	5	Moisture in finished paper	5
Miscellaneous uses	10	Miscellaneous loss/Open evaporation	18
Total water intake, m³/day=147		**Total water loss, m³/day = 147**	

*RO rejects are mixed in fresh water tank ** Average moisture: 7.5 %

c) Material Balance w.r.t. Inputs & Outputs During Paper Making

The major inputs & outputs involved in manufacturing of 90 tpd kraft paper is given in **Table-5.**

Table-5: Material Balance

Inputs, tonnes/day		Outputs, tonnes/day	
Waste Paper# • As such basis • OD Basis	 94.854 **87.740**	Finished Paper## • As such basis • OD Basis	 90 **85.05**
Additives/chemicals	**0.810**	Solid Rejects (Sand, sludge, plastic, pins etc.)	**3.000**
TDS carryover with paper sheet going to dryer section @ 45 % dryness	**3.367**	Solids dissolved in back water	**3.688**
Total	**91.917** **92 (approx)**	**Total**	**91.738** **92 (approx)**

Average moisture: 7.5 %, ##Average moisture: 5.5 %

d) Estimation of TDS, COD & BOD Generation Per Day in Back Water Due to Waste Paper & Chemicals/Additives Used by the Mill

As indicated earlier, **87.740 tonnes per day indigenous waste paper on OD basis** and the major additives/chemicals like Ultra bond (1.0 kg/t paper), Gum (4.0 kg/t paper) and Dye (4.0 kg/t paper) are used by the mill for paper making as per requirement of the product quality that is kraft paper. An attempt was made in CPPRI laboratory to estimate the generation of TDS, COD & BOD in back water due to waste paper & chemicals used. Waste Paper samples collected from the mill were processed at CPPRI in micro pulper under same conditions as adopted by the mill. The pollution load generated in terms of TDS, COD, BOD is indicated in **Table -6.**

Table-6: Estimated Generation of TDS, COD and BOD in back water

Particulars	kg/day	kg/tonne $_{\text{waste paper}}$
TDS generation	**3688**	**42.02**
COD generation	**3056**	**34.59**
BOD generation	**2160**	**24.45**

e) Estimation of the TDS, COD & BOD Concentration in Back Water at Which Their Generation Equal to Their Loss:

On the basis of estimated generations of TDS, COD & BOD per day in back water and total back water volume available in the closed system, the detailed calculation related to continuous accumulation of TDS, COD & BOD in back water due to its 100 % circulation in closed loop and the estimated concentration of TDS, COD & BOD at which their generations equals to their losses is indicated in **Table 7, 8 and 9** respectively:

Table- 7: Estimation of TDS Concentration of back water at which its generation equals to its loss

Particulars	Day					
	1st	**15th**	**30th**	**60th**	**90th**	**120th**
TDS generation, kg/day (Constant)	3688	3688	3688	3688	3688	3688
Back water in closed loop, m³/day	2500	2500	2500	2500	2500	2500

(Constant)						
TDS concentration in back water, gm/l	1.47	16.5	24.95	31.5	33.2	**33.7**
TDS loss, kg/day (Carryover with Finished Paper and solid rejects)	160.8	1798.3	3433.8	3621.3	3648.1	*3670.5*

Table- 8: Estimation of COD concentration of back water at which its generation equals to its loss

Particulars	Day					
	1st	15th	30th	60th	90th	120th
COD generation, kg/day (Constant)	3056	3056	3056	3056	3056	3056
Back water volume in closed loop, m^3/day (Constant)	2500	2500	2500	2500	2500	2500
COD concentration in back water, mg/l	1.22	13.67	20.7	26.1	27.5	**27.9**
COD Loss, kg/day (Carryover with finished paper and solid rejects)	133.2	4090.2	2253.7	2845.4	3000.7	3041.5

Table 9: Estimation of BOD concentration of back water at which its generation equals to its loss

Particulars	Day					
	1st	15th	30th	60th	90th	120th
BOD generation, kg/day (Constant)	2160	2160	2160	2160	2160	2160
Back water volume in closed loop, m^3/day (Constant)	2500	2500	2500	2500	2500	2500
BOD concentration in back water, mg/l	0.86	9.7	14.6	18.4	19.5	***19.7***
BOD Loss, kg/day (Carryover with finished paper and solid rejects)	94.2	1053.2	1592.9	2011.1	2120.9	2149.7

It is clear from above **Tables 7, 8 & 9** that the estimated concentrations of TDS, COD & BOD at which their generation per day due to process of waste paper & chemicals used by the mill equals to their losses per day due to carryover with finished paper & solid rejects are found as **33.7 gpl, 27.9 gpl & 19.7 gpl respectively.**

f) **Evaluation of TDS, COD and BOD Loss Due to Carryover with Finished Paper & Solid Rejects w.r.t. Their Estimated Generation Due to Waste Paper & Chemicals Used**

Table 10: Evaluation of TDS generation and its Loss

Particulars	**Values**
Back water carryover with wet paper sheet after press part	104 m^3 @ 31789 mg/l TDS
Back water carryover with solid rejects	5 m^3 @ 32224 mg/l TDS
TDS carryover with finished paper, kg/day	3306
TDS carryover with solid rejects, kg/day	161
Total TDS loss, kg/day	***3367***
Estimated TDS generation, kg/day	***3688***

Table 11: Evaluation of COD generation and its Loss

Particulars	**Values**
Back water carryover with wet paper sheet after press part	104 m^3 @ 25856 mg/l COD
Back water carryover with solid rejects	5 m^3 @ 26466 mg/l COD
COD carryover with finished paper, kg/day	2689
COD carryover with solid rejects, kg/day	132
Total COD loss, kg/day	***2821***
Estimated COD generation, kg/day	***3056***

Table 12: Evaluation of BOD generation and its Loss

Particulars	**Values**
Back water carryover with wet paper sheet after press part	104 m^3 @ 18522 mg/l BOD
Back water carryover with solid rejects	5 m^3 @ 19012 mg/l BOD
BOD carryover with finished paper, kg/day	1926
BOD carryover with solid rejects, kg/day	95
Total BOD loss, kg/day	***2021***
Estimated BOD generation, kg/day	***2160***

The results reported above in **Table 10, 11 & 12** indicate that the estimated generation of TDS, COD & BOD from waste paper & chemicals used by the mill is almost equal to their losses due to carrying over with finished paper & solid wastes at the concentration of these parameters analyzed in back water samples as indicated in **Table-3**.

Conclusion

As indicated in **Tables 7, 8 & 9** that the estimated concentration at which the addition of TDS, COD and BOD in back water per day equals to their loss due to carryover with finished paper & solid rejects is about **33.7 gpl , 27.9 gpl & 19.7 gpl respectively.**

As indicated in **Tables 10, 11 & 12** that the estimated generations of TDS, COD & BOD from waste paper & chemicals used by mill are in close proximity to their loss due to carrying over with finished paper & solid wastes at the concentration of these parameters analyzed in back water samples as indicated in **Table-3** which validates the ZLD status of the mill.

The RCF based kraft paper mills which have switched over to ZLD without any major technological intervention in general have to compromise with the product quality in terms of strength properties due to increase in anionic trash, ash content etc as well as reduction in wire & felts' life by 20- 40 %.

Further problem of odor in mills' atmosphere due to increase in temperature and formation of volatile fatty acids due to anaerobic condition, speedy corrosion of pipes and pumps, plugging of shower nozzles, deposits on wire, felts & press rolls, slime formation etc. are the major bottlenecks in going for ZLD without technology intervention.

Avoiding excess storage time in back water holding tanks and provision of air in the back water recycling tank can help in reducing the odor to a certain extent. Further, by selectively reducing the required make up water addition per day over a period of few days can help in replenishment of the old highly polluted back water in the circuit and thus reducing the odor.

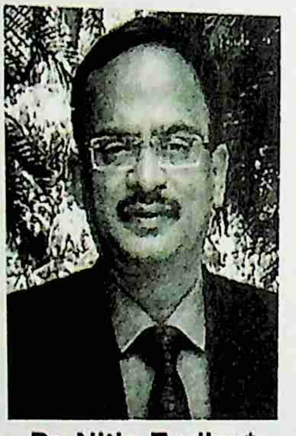
References

1. V. Hima Jwala, A.K. Vidyarthi, Kamlesh Singh, Techno-Economic Sustainable Option Adopting Aero Liquid Discharge in Waste Paper Based Pulp & Paper Industries, *IJETSR*, vol. 4, no. 9, pp. 898-907, 2017.

2. Nazih K. Shammas, Lawrence K. Wang, William A. Selke, Completely Closed Water Systems in Paper Mills, *Handbook of Environmental Engineering*, Volume 12.

3. Bruce Allender, Gogg Convey, Dennis Shore, Low-Effluent Recycled Paper Mills, *Appita Journal*, vol. 63, no.3, pp. 186-189, 2010.

Achieving of Zero Liquid Discharge through Biomethantion in a RCF based Kraft Paper Mill



Dr. Nitin Endlay*

Co-Authors

Mani Elanchezhiyan**, Mohd. Salim*, LeoHabets#, Suchit Dekivadia**, Jayakumar** & M.K. Gupta*

About the Author

Dr. Nitin Endlay holds M.Sc, PGDIPM and Ph.D. He is Scientist and Incharge of Environmental Management Division of Central Pulp & Paper Research Institute (CPPRI), Saharanpur.

He has over 28 years of working experience in the field of environmental management. His area of work include Biomethanation, Trouble shooting, Performance Evaluation and Adequacy Assessment of ETP, Water Conservation, Water Audit, EIA/ REIA, Odor Control, Environmental Monitoring etc.

He has assisted CPCB in various important activities related to pulp and paper industry, such as formulation / revision of environmental norms, Charter for Water Recycling and Pollution Prevention in mills operating in Ganga River Basin and Grossly Polluting industries.

He has published about 60 papers in national & international journals and prepared more than 250 technical reports during his illustrious career as prominent pulp and paper environmental scientist.

*Central Pulp & Paper Research Institute, Saharanpur, Uttar Pradesh, India.
**Paques Environnemental Technology India Pvt Ltd, Chennai, Tamil Nadu, India.
#Paper Water Advice, The Netherlands.

Abstract

With increasing emphasis on zero liquid discharge by regulatory authorities specially for recycled fiber based paper mills, a number of kraft paper mills producing paper from recycled fiber are reported to have closed their water loop with practically no technological intervention. In achieving so, the mills not only have to compromise on product quality, machine runnability, corrosion due to build up of pollution load like TDS, COD, BOD and other recalcitrant's but also have to suffer issues of Odour in surrounding environment as well as in product resulting in customer complaints and loss of market. In this context, Paques India's BIOPAQ® ICX (Internal Circulation Xperience) reactor offers a techno-economically feasible solution for RCF based kraft paper mills operating on ZLD to address issues / bottlenecks associated in achieving ZLD. The paper highlights a case study of a recycle fiber based kraft paper mill where the said reactor has been successfully set up and commissioned recently by Paques India to facilitate reuse / recycle of backwater in a closed loop so as to achieve zero liquid discharge along with cogeneration of biogas as well as address the issue of odour in paper and surrounding environment. The technology involves anaerobic treatment in bioreactor with advanced design and configuration which results in more than 90% reduction in VFA while the residual VFA is removed through post treatment by conventional activated sludge process in aeration tank. Reduction in over 65 - 70% of soluble COD (SCOD) in the backwater through BIOPAQ® ICX reduces treatment cost in terms of energy and chemical consumption in post treatment through activated sludge process. Optimisation of Calcium level in the water loop has been also achieved and is within the range of 450 mg/l – 600 mg/l compared to a level of 5000 mg/l before adoption of BIOPAQ® ICX installation. After implementing BIOPAQ® ICX the mill is able to produce odour free as well as food grade paper. The technology is now well proven and is ready for replication.

Keywords: BIOPAQ® ICX, Recycle fibre, VFA, SCOD, Closed loop, Biogas, Granular biomass, Odour, Calcium.

Introduction

Indian Paper Industry is unique in the context of having pulp & paper mills using diverse raw materials like wood, agro residues and waste paper / recycled fiber and producing a wide spectrum of paper products like packaging , writing and printing grade, news print, specialty paper etc. Over the years there has been a gradual shift in raw material usage from wood / agro residues to RCF / waste paper (imported / indigenous). Today out of 526 operating pulp and paper mills in the country (Total Pulp & Paper Mills are around 900) around 471 mills are RCF based pulp and paper mills. The major reasons for increased use of waste paper is comparatively simple process operation in processing waste paper as well as low pollution load than conventional wood / agro residue based paper making process.

Till a few years back the waste water discharge norms for RCF based paper mills was around 50 m^3 / t paper . However with implementation of Charter for Water Recycling & pollution Prevention in Pulp & Paper Industries of Ganga River Basinthe norms for fresh water consumption & waste water discharge norms were made significantly stringent and are summarized in Table 1 & Table 2.

Table 1: Fresh Water Consumption & Waste Water Discharge Norms under Charter.

Mills Category	Fresh Water Consumption m^3 / t paper	Waste Water Discharge Norms ., m^3 / t paper
RCF based Pulp & Paper Mills producing Bleached Grade of paper	15	10
RCF based Pulp & Paper Mills producing Unbleached Grade of paper	10	6

Table 2: Discharge Norms for RCF based Pulp & Paper Mills under Charter.

Parameters	RCF based Mills
pH	6.5-8.5
TSS,mg/l	< 30
TDS, mg/l	<2100
COD, mg/l	< 150
BOD , mg/l	< 20
Colour , PCU	< 350
AOX , mg/l	<5
SAR	< 8

The same standards are proposed to be enforced on national level soon. With increasing surveillance as well as stringent pollution load norms achieving environmental compliance has become a challenging task and requires adequate process optimisation, technological as well as ETP upgradation toreduce water consumption and consequently waste water discharge as well as achieve environmental compliance. As such in recent times many RCF based pulp & paper mills particularly producing unbleached grade of paper have opted for zero liquid discharge (ZLD) by closing their water loop with practically no or minimum technological intervention, to overcome the challenges of environmental compliance and save ETP operation cost. The reduction in fresh water consumption through reuse / recycling of back water / treated effluent leads to build up of TDS, COD, BOD and other recalcitrantsin the water circuit which becomes difficult to be treated through conventional ETP based on biological treatment process. The waste water / back water from RCF based Kraft Paper Mill operating on ZLD without biological treatment thus usually contains high COD, BOD, VFA, TSS, TDS, Calcium, Sulphate, etc. High VFA leads to slime formation and odour issue. Further these mills have to also compromise with product quality, machine runnability, equipment's corrosion due to build up of TDS, recalcitrant's, COD & BOD. Even some of the state regulatory boards are now issuing directions to RCF based paper mills to shift to ZLD in a fixed time frame.

In this perspective Paques India's BIOPAQ® ICX (Internal Circulation Xperience) technology was recently commissioned at a RCF based kraft paper mill which offers an interesting case study to address these bottlenecks in operation on ZLD.

Brief Profile of the mill

The mill is a 150 tpd RCF based kraft paper mill and produces around various grades of kraft paper.

This mill also opted to operate in closed loop so as to achieve ZLD without any technological intervention or biological treatment. Soon the mill struggled with product quality as well as odour in product and the environment due to build up of soluble COD, volatile fatty acids (VFA), calcium, etc. which forced the mill to explore the appropriate technology to address these issues. In this perspective Paques India's BIOPAQ® ICX (Internal Circulation Xperience) technology offered viable solution to the above issues.

Paques India's BIOPAQ® ICX (Internal Circulation) Technology– Mechanism

Paques is a global market leader in the field of anaerobic treatment. Its reactor BIOPAQ® UASB reactor is already a proven technology and has been widely installed in various industrial sectors around the globe. BIOPAQ® IC reactor is a new generation dynamic reactor recently introduced to treat wide range of organic pollutants, i.e. from 1,000 to 20,000 mg COD/l.

The BIOPAQ® ICX Reactor (Fig.1), recently commissioned at this RCF based kraft paper mill is the company's third generation anaerobic reactor incorporated as a pre -treatment step before conventional aerobic treatment for handling the back water of the paper mill. The anaerobic reactor is designed to biologically convert organic pollutants (measured as COD) present in the wastewater into biogas. The major merits associated with BIOPAQ®ICX reactor are :

- Reduction of VFA in water loop to ensure odour free paper production.
- Co-geneartion 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 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 acidification process occurs partly in the pre-treatment upstream of the anaerobic reactor (e.g. buffer/acidification tank) as well as inside the anaerobic reactor. The acidification which takes place upstream of the anaerobic reactor is called "pre-acidification". In most cases a certain degree of pre-acidification is desired, because it enhances the performance of the anaerobic reactor and the biomass quality inside the anaerobic reactor.

In the reactor the anaerobic micro-organisms convert the COD present in the pre-acidified wastewater into methane (CH_4) and carbon dioxide (CO_2). The generated biogas is collected in the headspace of the reactor and subsequently transported to a gas buffer or other gas processing unit. The treated wastewater is separated from the biomass in the separators and leaves the reactor with a significant reduction in its COD concentration.

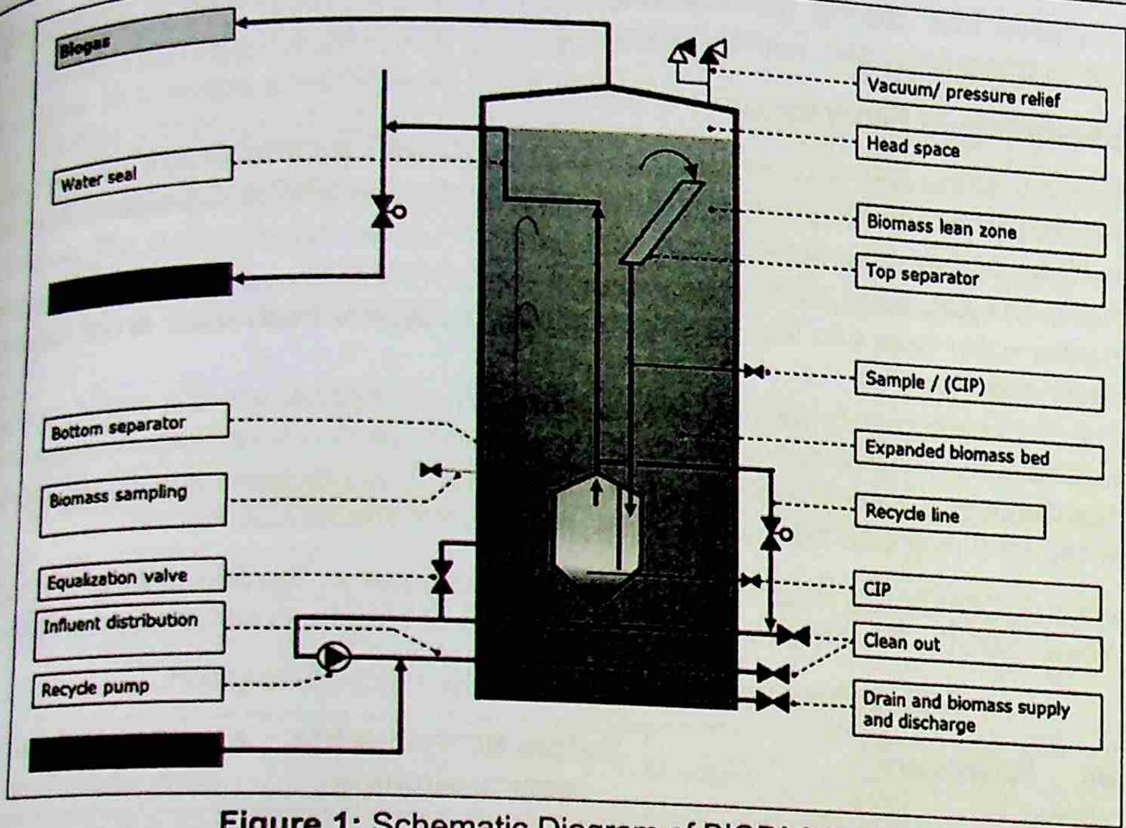


Figure 1: Schematic Diagram of BIOPAQ® ICX.

Besides the formation of biogas from COD, sulphurous compounds (sulphate, sulphite, thiosulphate and sulphur) are converted into hydrogen sulphide (HS-) by sulphate reducing bacteria, which leads to the presence of H_2S in the biogas. This reaction is unwanted because it consumes COD, which cannot be used for methane production and the formed H_2S is toxic, corrosive and odorous; this reaction however cannot be avoided.

The performance of the reactor depends on several parameters of which the major one are as under :

- The quantity and the quality of the biomass in the reactor.
- The composition of the wastewater to be treated (COD composition, presence of toxic components).
- The operation conditions of the reactor (e.g. temperature, pH, recycle flow rate etc.).
- The absence/presence of nutrients (macro and micro nutrients).
- The performance of the pre-treatment.

Closed Loop System at the Selected RCF based Kraft Paper Mill

e closed water loop established at the RCF based kraft paper mill is indicated in Fig 2. The esh water is mainly added on paper machines as make up water to compensate the water s due to evaporation in paper machine. The back water from paper machine is collected in collection tank followed by fiber recovery in sedicell. The sedicell outlet is sent to conditioning nk / buffer tank where macro / micro nutrients required for growth of anaerobic microbes are ed and pH is regulated. This is followed by anaerobic treatment through Biopaq® ICX reactor ere the anaerobic microbes convert the biologically degradable organic matter into biogas. he anerobically treated backwater is post treated anaerobically through aeration tank and followed / secondary clarifier to arrest the loss of biomass.The secondary clarifier overflow is reused in stock preparation thus closing the water loop. The DAF sludge & Secondary Clarifier Sludge is dewatered in screw press and sold to contractors.

Commissioning of Bioreactor

Commissioning of the ETP kick started on 20.07.2020 with BIOPAQ® ICX reactor and the plantremarkably stabilized within 2 weeks. After implementing BIOPAQ® ICX system the mill has been benefitted on following counts:

- Due to adequate biological treatment system the mill is able to now recycle 100% secondary clarifier water back into the process therefore, additional fresh water is not required for paper making.
- The fresh water requirement is now only 1 to 1.5 m^3 / t paper which is added as make up water to compensate water evaporated in evaporation section during paper making process.
- The Odour issue in paper has been resolved due to significant reduction in COD & VFA in the water loop after treatment through Paques BIOPAQ® ICX reactor.

Advantage of BIOPAQ® ICX reactor in treating the backwater in the closed loop and reducing TDS, Calcium, SCOD, VFA etc as well as cogeneration of biogas is summarized in Table 3.

Table 3: Machine back water characteristics comparison.

S.No.	Parameters	Before BIOPAQ® ICX commissioning	After BIOPAQ® ICX commissioning
1	pH	5.56	6.5 - 7.2
2	TSS (mg/l)	800	< 300
3	TDS (mg/l)	24400	< 9000
4	Calcium (mg/l)	5130	< 500
5	VFA (meq/l)	300	< 30
6	Paper odour	Yes	No
7	SCOD (mg/l)	57700	<5000
8	Biogas generation (m^3/d)	0	2000 - 2500

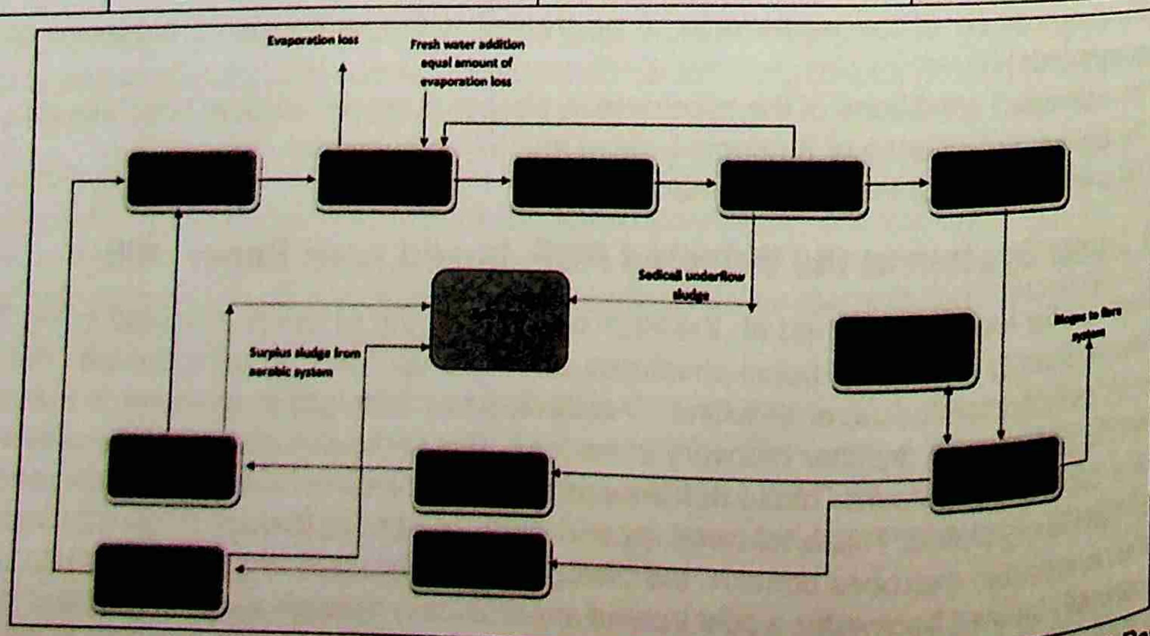


Figure 2: Layout of Closed Loop/ZLD Circuit with Biopaq® ICX Reactor at RCF based Kraft Paper Mill.

Performance Summary of BIOPAQ® ICX reactor

The above table indicates the efficiency and suitability of the BIOPAQ® ICX reactor in waste water treatment so as to enable a RCF based Kraft Paper Mill to operate in a closed loop / zldZLD as well as produce odour free paper. After its commissioning VFA and SCOD in the water loop has reduced by over 10 times i.e. up to 20 meq/l and 5500mg/l (Fig 3) . Similarly as indicated in Fig 4VFA has been found to be in range of just 20 to 30 meq/l after treatment which helps in reducing Odour issue. The overall performance efficiency of Biopaq® ICX Reactor is summarised in Fig 5.

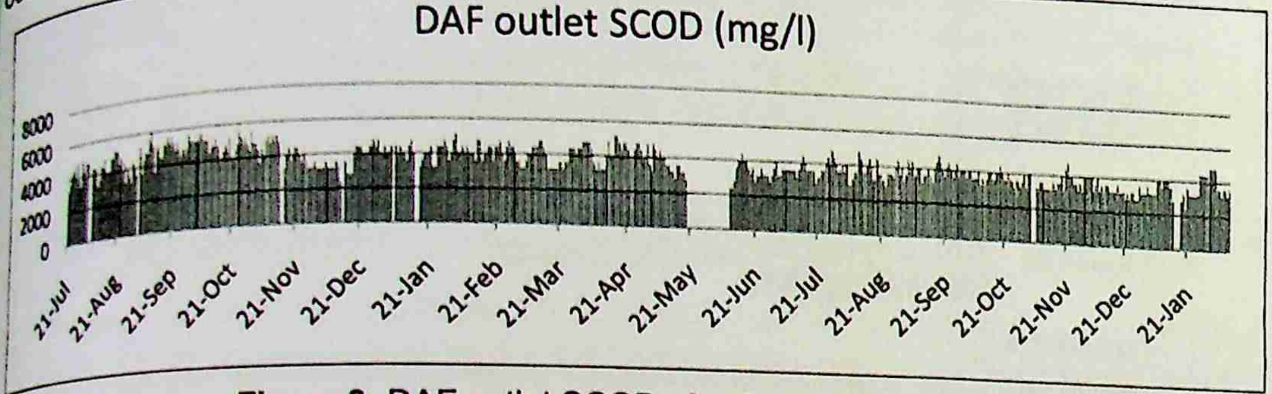


Figure 3: DAF outlet SCOD after Bio methanation.

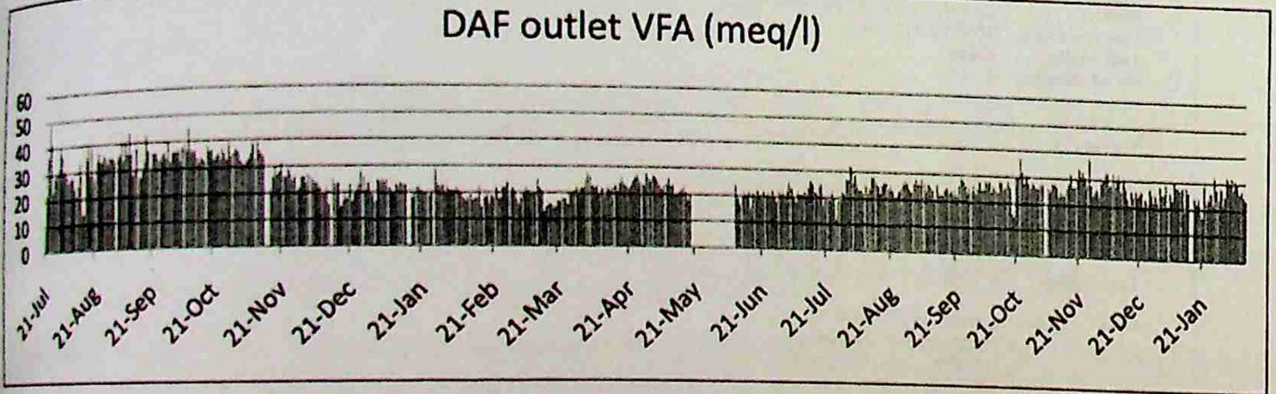


Figure 4: DAF outlet VFA after Biomethanation.

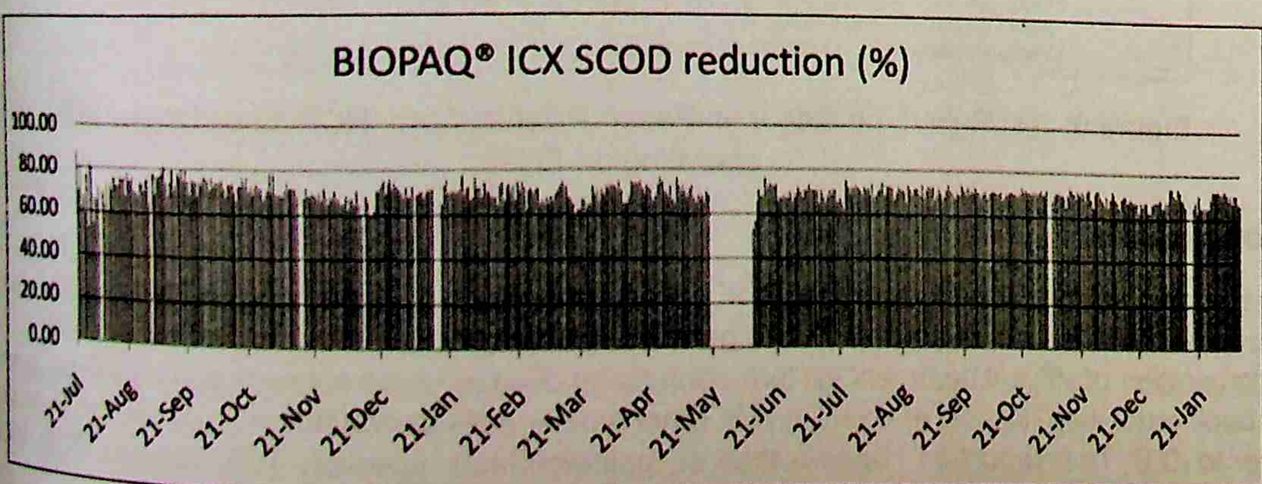


Figure 5: ICX SCOD efficiency.

Elimination / Control of Odour in Paper

Odour in paper which has been a major issue before the RCF based kraft paper millsoperating on ZLD,has been successfully addressed through BIOPAQ® ICX reactor. The major factors for odour in the paper are uncontrolled Volatile Fatty Acids (VFA) and Sulphides. These two organics and inorganics creates a foul smell due to increased build up in concentration when the back water is recycled several times in closed loop. The combination of adequate anaerobic and aerobic treatment, like the present case study,of offers is a techno-economically feasible solution to this problemand thus facilitate production of odour free paper along with complete recycling and reuse of treated effluent. The kraft paper from this RCF based kraft paper mill, operating on ZLD / closed loop, has also been tested / certified as odour free & suitable for food grade products by renowned testing agency, SGS Laboratories.(Fig 6)

SGS

TEST REPORT

Report No. : MAN:HL:1248003187 **DATE :19th May, 2021**

TEST RESULTS:

GERMAN FOOD, ARTICLES OF DAILY USE AND FEED CODE OF SEPTEMBER 1, 2005 (LFGB), SECTION 30 & 31 WITH AMENDMENTS:

SENSORY EXAMINATION – ODOUR AND TASTE TEST:

Method: With reference to DIN10955: 2004
Test condition: 40°C for 2 Hours
Test media: Bread
No. of panelist: 6

Test Result:

Test Media	Test Item	Result		Maximum Permissible Limit
		1	2	
Bread	Sensorial examination odour	0	0	2.5
	Sensorial examination taste	0	0	2.5
Conclusion		Pass	Pass	–

Tested Item: 1. 180 GSM Kraft Paper, 2. 200 GSM Kraft Paper

Note: 1. Intensity scale (rounded at 0.5):
0 – no perceptible difference
1 – just perceptible difference
2 – slight difference
3 – marked difference
4 – strong difference
2.Permissible Limit is according to German Food, Articles of Daily Use and Feed Code of September 1, 2005 (LFGB), Section 30 & 31 with Amendments.
3.Testing has been performed as per client's request

Figure 6: Test Report on Odour in Paper Product from RCF based Paper Mills operating on ZLD.

Conclusion

The success of the case study of this RCF based kraft paper mill operating on ZLD in addressing the contentious issues related to ZLD operation specially odour in paper and paper products by incorporation of effluent treatment system comprising of anaerobic treatment and aerobic treatment in back water loop has set an example for other similar mills operating on ZLD / wishing to switch over to ZLD. The reduction / optimisation of pollution load specially TDS, calcium, COD, VFA etc has helped the mill in overcoming the bottlenecks in ZLD operation like adverse impact on product quality, machine runnability, VFA and odour in paper and surrounding environment. The co generation of biogas is an additional advantage along with water conservation and elimination of waste water discharge. In all, the Paques India's BIOPAQ® ICX (Internal Circulation Xperience) is now a proven technology and is ready for replication.

rences

CPPRI Statistical Cell.

CPCB Report: Charter for Water Recycling & Pollution Prevention in Pulp & Paper industries in Ganga River Basin.

CPCB Report: Techno-economic feasibility in Setting Up CCRP & CETP in Pulp & Paper Mills located in the Cluster.

Compendium of Census Survey of Indian Paper Industry, CPPRI publication.

Habets, L.H.A. and W. Driessen; (2016); scaling up by anaerobic pretreatment, scaling down operational cost and effluent figures; IPPTA -The Official International Journal; Volume 28; No 3. July – September 2016 5.

6. Werfhorst Van de, HabetsL.H.A. and BoulengerP; (2006); Producing paper without producing effluent, A case study; PITA Conference UK 2006.

7. TielbaardM, Noordink and HabetsL.H.A, (2018); Treatment and re-use of paper mill effluent, using a breakthrough anaerobic reactor; Tappi Papercon April 15 – 18; Charlotte NC, USA7.

8. NoordinkM, HabetsL.H.A, PrinsR, SteffaniJ. De, DekivadiaS(2018); A breakthrough Biopaq anaerobic reactor proves itself in the pulp and paper industry (2018); IPPTA Journal Vol.30 nr.1; March 2018.

9. Endlay Nitin et.al(2015); Reducing environmental footprint through holistic approach – a case study of pulp & paper mills in Kashipur Cluster, IPPTA, 27 (4), 2015.

10. Driessen W.J.B.M. et.al(1999); Anaerobic Treatment of Recycled Paper Mill Effluent with the Internal Circulation Reactor, Proceedings of 6th IAWQ sypmposium on Forest Industry Waste Waters, Tampere, Finland, 6-10 June 1999.

11. HabetsLeo H.A & Heins, J. Kneliissen(1999); In Line Biological Water in a Zero Discharge Recycle Paper Mill, Water Science & Technology, 35(2), December 1999.

12. Panwar S, Endlay Nitin, Pandey A & Mathur R.M(2001);Biomethanation Technology – An Option for Treatment of Effluent Generated in Recycled Fiber based Mills, IPPTA , 13 (3), 2001.

****