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

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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	140
m^3 / t paper	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

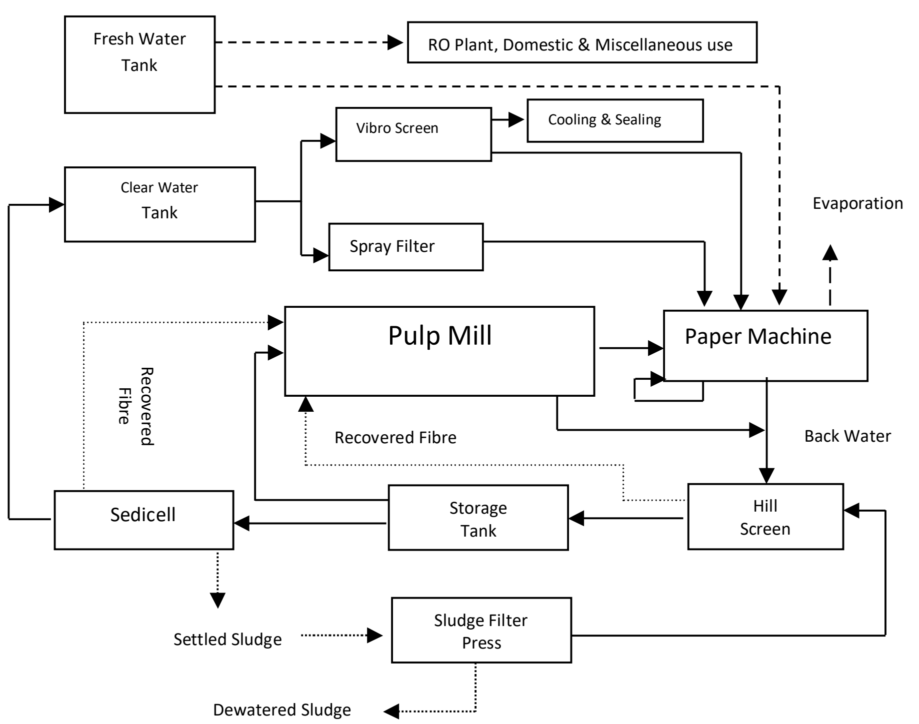

Fig.-1: The back water reuse & recycling system in the selected RCF based kraft paper mill

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**

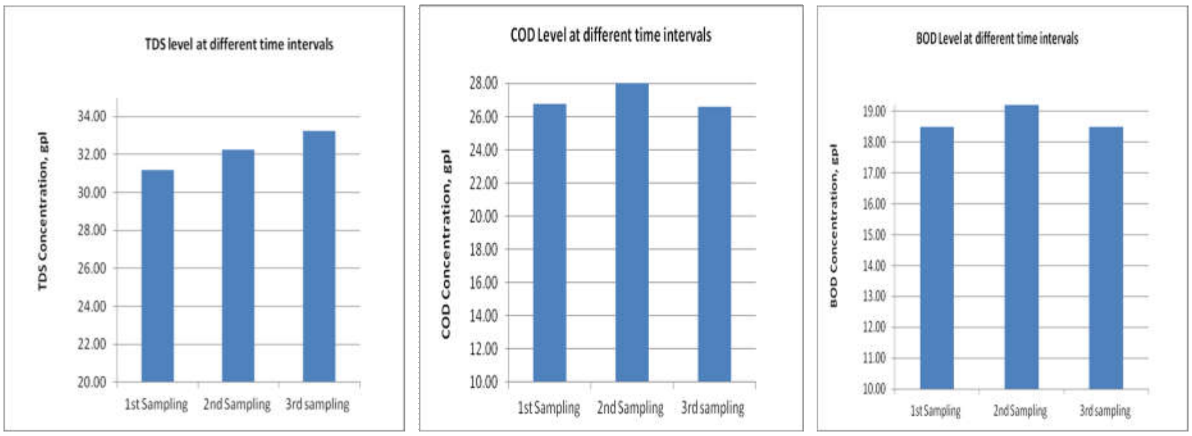

Fig.-3: Almost constant level of TDS, COD & BOD in clear back water collected at different time intervals

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, m^3/day		Water Loss, m^3/day	
Paper machine	**90**	Evaluation 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, m^3/day=147		**Total water loss, m^3/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, m^3/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.

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