Comparative Analysis of XL-2 Projects
(Third Report for IP XL-2 Project)

By

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Introduction

The goal following the three-year XL project is 26 kg COD per unbleached ADMT (air-dried) metric ton based upon a monthly average. The long-term color goal is 50 pounds per U.S. ton (air-dried) of Kraft pulp produced as a quarterly average limitation. No toxicity standards are contained in the performance goals. Additionally, International Paper Company has agreed to spend $780,000 in capital and engineering cost to implement process modification projects to meet the effluent reduction goals of the project. This amount is the equivalent financial obligation that would have been spent to comply with the Best Management Practice provisions of the Cluster rules.

In the Interim Report of October 18th, 2000 a two-pronged approach was recommended to achieve the goals and intent of the XL-2 project.

1. **Identify and Implement COD Reduction Projects.** The first stratagem recommended to the Collaborative Team was to continue to identify and implement projects which lead to reduced black liquor discharges from the pulp mill, bleach plant and recovery area.

2. Reduce COD and Color Discharge in the Effluent from Paper Machines. The second stratagem was to stimulate actions that lead to reduction in COD and color originating from the five (5) paper machines at the Androscoggin mill. Without a reduction in COD from the paper machines it is doubtful that the COD effluent release goals of the XL-project would be met.

This two-pronged approach was necessitated because the results of the mill-wide BOD/COD balance showed that most of the organic material in the mill effluent originates from the paper machines and associated coating operations. Organic material originating from the paper mill was shown to be relatively resistant to removal in the waste water treatment plant, but is relatively low in toxicity. By contrast, considerably smaller amounts of organic material are released from the black liquor cycle, which moreover is more efficiently removed in the waste water system. However organic compounds in the effluent released from the black liquor cycle, predominately lignin degradation and bleached lignin products, are known to have a much higher toxicity than material from the paper mill.

Thus, reduced discharge from the paper mill would help achieve the COD emission goal of the XL project, while increased system closure of the black liquor cycle will address the intent of the project, which is to reduce the toxic effects of the mill discharge. The two-stratagem approach adopted by the Collaborative Team is also thought to be effective for achieving the effluent color goal of the XL Project. Color in the final mill effluent going to the Androscoggin River would be expected to correlate both with release of organic compounds in the black liquor, measured as COD, and effluent originating from the paper mill if TiO_2 is used in the coating operation. This latter conclusion is inferred from information contained in NCASI Technical Bulletin 803, May 2000.

At the October 16, 2000 XL project review meeting, these recommendations to achieve the XL-2 project goals were approved by the Collaborative Team. It was understood by the stakeholders that the effluent from a Kraft pulping operation with integrated coated paper mill, as present at the IP-Jay, Maine facility, represents a unique situation that requires a flexible approach in agreement with the mission of the XL program of Excellence, Leadership and Transferability.

The COD reduction projects approved and implemented so far have dealt with the minimization of the release of black liquor from the screen room of the pulp mill. Although the Technical Team and the Collaborative Team will continue to focus on the black liquor cycle, it will also stimulate actions to reduce discharges from the paper mill. It will do this by measuring and documenting the discharges from the paper mill, and by inviting the management and technical staff of the paper mill to become involved in achieving the environmental goals of the XL-2 program. The present report focuses on the quantification of the impact of implemented, approved and potential new projects to reduce the discharge of COD from the black liquor cycle.

COD From Mill Production Units

The mill-wide COD/BOD balance identified that the discharge from the pulp mill represents about 151,000 lbs COD/ day, compared to about 495,000 lbs COD/day for the entire mill based on the summative analysis results. When normalized in terms of unbleached pulp production of approximately 1000 MT/day, these discharges are

approximately 69 and 225 kg COD/MT respectively. Based on measurements at the inlet of the wastewater treatment system, the discharge of the entire mill was found to be 181 kg COD/MT. This value is smaller than the summative result of 225 kg COD/MT because of measurement errors and possibly removal of part of the organics during transport in the sewers to the treatment plant.

After treatment in the wastewater facility, the COD discharges reported above are strongly reduced. However, the removal efficiencies of the organic material for each of the different waste streams are not known. The overall efficiency for COD removal in the wastewater treatment plant is approximately 81% and is estimated based on data developed for the mill-wide COD balance. The range of the treatment efficiencies for the various organic compounds in the effluent originating in the black liquor cycle can be estimated as 50-100%, and for the paper mill as 77-100% -- again using data from the mill-wide balance. Although it is expected that the COD removal efficiency of the pulp mill organics will be higher than that of the styrene-butadiene latex containing organics of the paper mill, the overall efficiency of 81% will be used for all discharges. Thus, the contribution of the discharge of the pulp mill to the final effluent is estimated as (1-.81)x(69/225)x181= 11 kg COD/MT pulp compared to (1-0.81)x181=34 kg COD/MT pulp for the entire mill.

COD Contributions in Various Pulp Mill Streams

The COD contributions of the different sewer streams of the pulp mill measured as part of the Mill-Wide COD Balance are listed in Table 1. The softwood pulp mill is denoted as “A” in Table 1, while “B” is used to indicate the hardwood pulp mill. The softwood and hardwood mills represent respectively 60% and 40% of the total pulp production.

The results in Table 1 show that the bleach plant as the sum of the chlorine dioxide (D) and caustic extraction (E) filtrates generates the largest COD discharge. The separate contribution of turpentine in the A caustic sewer can be estimated using the mill measured BOD value of the flash steam condensate of 4,200,000 lb./year or, after normalization by the entire pulp production, 5.2 kg BOD/MT pulp. Assuming the same COD/BOD ratio of 1.7 as measured for the evaporator condensate sewer stream (see

Table A1 of the Interim Report for IP XL-2 Project, October 18, 2000), the contribution by the turpentine is estimated at 8.9 kg COD/MT pulp or 13% of the normalized discharge. This value can be converted into a turpentine generation rate of 5.1 liters/MT of softwood pulp using the theoretical value of 2.9 kg COD/liter turpentine contributed by 60% 0f the pulp production. This compares reasonably well with an average turpentine production figure of 6.4 liter/ton of pulp reported in literature (G.C. Landry et al., Tappi J., 68(4), 98-102(1985)).

Table 1

COD Contributions of the Pulp Mill Streams

Sewer Stream	**Process Stream**	**Normalized Discharge (before treatment)**	
		(kg COD/MT pulp)	**(%)**
A+B Acid	D filtrates	20	29
Evaporators	A+B Evaporator Condensates	12	18
A caustic	Turpentine + E filtrates	15	21
B caustic	E filtrates	10	15
A+B General	Screen Room	12	17
Total Black Liquor Cycle		**69**	**100**

It is also instructive to make a comparative estimate of the COD generation by an ECF bleaching process as used by IP. The normalized COD discharge for an ECF softwood Kraft pulp bleaching effluent (unbleached kappa number of 30-37) is reported to be 34-60 kg COD/MT pulp (Dence and Reeve, "Pulp Bleaching; Principles and Practice", pg753 (1996)). Based on the average kappa number of 19 at IP for the combined softwood and hardwood pulp stream (60% softwood of 20.5 post O_2 kappa, 40 % hardwood of 16.3 kappa), the bleach plant COD contribution is estimated as 19x(34+60)/(30+37)=27 kg COD/MT pulp. Again this estimate is comparable with the

sum of the measured COD contributions of the acid and caustic sewers (see Table 1) minus the contribution of turpentine (8.9 kg COD/MT) as 20+15+10-8.9=36 kg COD/MT pulp. Thus, the measured COD contribution by the bleach plant appears reasonable, and represents (36/69)x100=52% of the discharge associated with the black liquor cycle.

Finally, the combined softwood and hardwood evaporator condensate discharge of 12 kg COD/MT listed in Table 1 may be compared to a range of 15-22 kg COD/MT reported for softwood black liquor condensates (P. Axegard, "Ecocyclic pulp mill, Final Report", 165(2000)). The slightly larger relative difference might indicate that the COD discharge from the combined evaporator condensates is somewhat larger than 18% of the pulp mill discharge listed in Table 1.

Implemented and Approved Projects for Pulp Mill COD Reduction

All the implemented projects as part of the XL2 project have been in the screen room of pulp mill A and B. The projects are listed in Table 2. The results in Table 2 show that the implemented projects reduced the COD discharge by the pulp mill by an estimated 10% relative to the situation during the Mill-Wide COD Survey in August 2000. In other words, these projects reduced the discharge of COD from the pulp mill from 76 to 69 kg COD/MT of pulp.

Also listed in Table 2 are two additional approved projects. Implementation of these two projects will reduce the COD discharge further to an estimated 63-kg COD/MT pulp. To put these numbers in perspective, it is useful to estimate their impact on the COD content of the final effluent. Assuming a COD removal efficiency of the waste water treatment facility of 81 %, the COD reductions of 7 and 4 kg COD/MT pulp by the implemented projects and approved projects result in reductions of 1.3 and 0.8 kg COD/MT pulp respectively. As pointed out in the previous Interim Report for the XL2 project, these reductions are small compared to the total mill discharge of 34 kg COD/MT pulp, and are insufficient to achieve the COD goal of 26 kg COD/MT pulp. However, in terms of the newly adopted strategy for the XL2 project, the implemented projects are highly significant in that they reduce the COD discharge of the pulp mill by 10 and 5.7% respectively.

Table 2

Implemented and Approved Projects

Source	Project	Pulp Mill COD Reduction		Cost
		(kg COD/MT)	(%)	($1000)
"A" sluice filtrate	Use cyclone water	0.9	1.2	4
"B" sluice filtrate	Pipe to process; improve "B" screen efficiency	1.4	2.0	0
"B" screenings sluice filtrate	Use cyclone water	0.6	0.9	3
"B" cleaner rejects	"B" screen upgrade	4.1	5.9	120
Implemented		**7.0**	**10**	**127**
"A" screenings sluice filtrate	Replace with PM white water	2.6	3.7	45
"B" cleaner rejects	Installation of timed dump of cleaner	1.4	2.0	35
Approved		**4.0**	**5.7**	**80**

Potential Pulp Mill Projects for COD Discharge Reduction

From the analysis of the results in Table 1 it was estimated that 52% of the COD discharge by the pulp mill is coming from the bleach plant, 18% from evaporator condensates, 13% from turpentine of the "A" mill, and 17% from the screen rooms and miscellaneous sources. These results are summarized in Table 3.

Obviously, the largest reduction in COD discharge can be achieved by system closure of the bleach plant. However this is unrealistic with the present state of technology and bleach plant water usage. What can be done, however, is to reduce the kappa number of the pulp entering the bleach plant. This can be achieved by extended cooking and by O_2 delignification in the softwood pulp mill (Mill A). The former is not the preferred option because it leads to a lower bleached pulp yield. Thus, the two

potential projects listed in Table 3 to reduce the COD contribution of the bleach plant are Project 1, Increase/ Improve O_2 Delignification, and Project 2, Improve Post O_2 Washing.

Table 3

Potential Pulp Mill Projects

Process Source	**COD Contribution**		**Potential Projects**
	(kg COD/MT)	**(%)**	
Bleach Plant	36	52	**1.** Increase/Improve O_2 Delignification **2.** Improve Post O_2 Washing
Evaporator Condensates	12	18	**3.** Condensate Stripping **4.** Reverse Osmosis on Stripped Condensate **5.** Reuse of the Stripped Condensate
Turpentine	9	13	**6.** Minimize Black Liquor Carry-over **7.** Turpentine Recovery
Screen Room + Miscellaneous	12	17	**8.** Knots and Screenings Processing **9.** Sewer Conductivity and Flow Monitoring
Black liquor Cycle	**69**	**100**	

Project 1 also includes better brown stock washing in order to increase the efficiency of O_2 delignification. Presently, the mini-O_2 delignification stage at IP reduces the softwood kappa number from about 28.5 to approximately 20.5. This represents a delignification reduction of about 28%, and is significantly lower than the typical 50-60% reduction normally achieved on softwood in a well designed commercial system. In the mini-O_2 system operated in the A mill at Jay, the first pressurized reactor has a residence time of 20 minutes and is operated at approximately 90 to 100 psig. Unfortunately the second reactor operated following the blow tank is a converted up-flow bleaching tower that is operated at atmospheric pressure. Without a pressurized second reactor, the normal second phase of the oxygen delignification reactions does not occur to a significant extent. Assuming that the delignification efficiency can be improved to 40% by improved washing and optimization of the O_2 delignification system, this would result

in a reduction in the COD discharge by an estimated 3% of the total pulp mill discharge, that is, (0.40-0.28)x28.5x0.6x0.96=2 kg COD/MT pulp. In the above calculation, the values of 0.6 and 0.96 are respectively the fraction of the pulp production represented softwood, and the decrease in kg COD per unit kappa number decrease of softwood pulp entering the ECF bleach plant.

Of the other potential projects listed in Table 3 to reduce COD discharge in the mill effluent, the largest impact can be expected from Project 3, Condensate Stripping, and Project 7, Turpentine Recovery. The remaining projects listed in Table 3 are significant for a variety of reasons. Project 4, Reverse Osmosis on Stripped Condensate is advantageous from the point of view of reducing toxicity in the mill effluent while Project 5, Reuse of the Stripped Condensate, could significantly reduce the water usage by the mill. Project 8, Knots and Screenings Processing, would reduce the solids going to the landfill reduction, improve the pulp yield and reduce wood cost. Lastly, Project 9, Sewer Conductivity and Flow Monitoring, would potentially have the benefit of assisting in monitoring discharges from the paper machines and other point sources from the mill.

All projects listed in Table 3 need to be further analyzed in terms of technical economics and their impact in kg COD/MT of pulp removed per unit of capital investment required. This will be the next main task for the Technical Team on the XL-2 Project, besides actions to stimulate reduction of the discharge of organic material and pigments from the paper machines.

Conclusion

The COD discharge from the black liquor cycle is estimated to be approximately 69 kg COD/MT pulp. This represents about one-third of the total COD discharge by the entire mill complex. The projects implemented under the XL-2 project have resulted in a reduction in COD discharge of about 10% relative to the situation that existed in August 2000. In other words, these projects reduced the COD discharge of the pulp mill from about 76 to 69 kg COD/MT pulp. The projects implemented to date have resulted from closing up the screen rooms in the A and B pulp mills. Implementation of the two remaining approved projects will bring the COD discharge further down to an estimated

63 kg COD/MT pulp. The implemented and approved represent about 2 Kg COD/MT going to the waste treatment plant, which is insufficient to meet the COD goal.

It is estimated that 52% of the COD discharge by the pulp mill is coming from the bleach plant, 18% from evaporator condensates, 13% from turpentine of the "A" mill, and 17% from the screen rooms and miscellaneous sources (Table 3). Nine potential projects have been identified to further reduce the COD discharge by the pulp mill. Of these the largest impact can be expected from the **"**Condensate Stripping" and the "Turpentine Recovery" projects. Improving the efficiency in the oxygen delignification process not only has the advantage of reducing the COD and toxicity discharges from the A pulp mill but also reducing ClO_2 consumption and operating cost on the softwood line.