

Treatment efficiency of eucalypt kraft pulp bleaching effluents: influence of dissolved organic matter

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ABSTRACT: This study compared the treatability of laboratory generated eucalyptus kraft pulp elemental chlorine free (ECF) and totally chlorine free (TCF) bleaching effluents in a bench-scale activated sludge system. We separated untreated and treated effluents by ultrafiltration into three fractions with molecular masses <500 Da, between 500 and 3000 Da, and >3000 Da to study the contribution of each fraction to whole effluent values before and after treatment. Untreated TCF effluent presented 3.75 times as much BOD and 2.4 times as much COD as ECF effluent. Over a six week treatment period, BOD removal was similar for both effluents (>97%). However, COD removal was greater in TCF (77%-85%) than in ECF (47%-68%) effluent, attributed largely to the removal of high molecular mass organic matter, which represented a significant fraction of TCF effluent but not ECF effluent. Microtox toxicity was consistently eliminated from both effluents, whereas chronic toxicity to algae was reduced but not removed during treatment. Effluent toxicity was not correlated with BOD, COD, or AOX levels. TCF effluent contained more readily removable high molecular mass organic matter than ECF effluent. Removal efficiency was not simply a function of organic matter molecular mass, but also of the nature of the dissolved organic matter. The ECF effluent fraction of intermediate molecular mass was the most highly chlorinated and presented the lowest removal efficiency.

Application: Knowing how effluent composition affects treatment efficiency can help mills manage their treatment systems in ways that avoid treatment efficiency loss after mill process changes.

Elemental (ECF) and totally (TCF) chlorine free bleaching effluents are believed to be equally treatable in efficiently operated treatment plants [1]. However, the literature presents contradictory results of the comparative effects of ECF and TCF effluents [2-4]. Model ecosystem studies indicate a correlation between effluent COD and adverse effects observed, such as toxicity. That suggests that a decrease in the amount of dissolved organic matter liberated to the environment is more important than the type of bleaching practiced for improvement of effluent quality and reduction of the adverse environmental effects of effluents [4]. Treatment efficiency can be reduced after altering the production process between periods of ECF and TCF bleaching because of the period of adaptation of sludge microorganisms to the new chemical composition of the effluent [1,5,6]. If we consider COD to be the determining factor of the adverse effects of the effluents in aquatic ecosystems, we should minimize the COD remaining after treatment, which represents refractory organic matter. Evidence exists that

the proportion of organic matter with molecular mass >1000 Daltons (Da) increases after biological treatment [7-10], suggesting a lower biodegradability of the high molecular mass (HMM) matter. Improvements in removal of the more refractory organic matter will lead to greater COD reduction efficiency and better quality treated effluent. An understanding of the effect of process modifications—such as switching between production of ECF and TCF pulps—on treatment efficiency and the nature and biodegradability of the HMM organic matter dissolved in these bleaching effluents will provide information for the development of methods to increase removal of refractory organic matter during treatment.

The objective of this study was to compare ECF and TCF eucalypt kraft pulp bleaching effluent treatment efficiency in an activated sludge system. We were especially interested in the capacity of sludge microorganisms to degrade HMM organic matter in the effluents and the importance of adaptation of the microorganisms to treatment efficiency.

MATERIAL AND METHODS *Bleaching effluents*

A Brazilian mill provided the oxygen delignified eucalypt kraft pulp. The pulp had a kappa number of 14.0, viscosity of 31.9 mPas, and 44.3% ISO brightness. ECF and TCF bleaching effluents were produced using the sequences D(EO)DD and Q(OP)(ZQ)(PO), respectively, to produce pulps with 88% ISO final brightness (Table I). We used polyethylene bags in a vapor bath equipped with a thermoregulator for the D and Q stages. The Z, (EO), (OP), and (PO) stages were carried out in a teflon lined Quantum Mark IV (Twinsburg, Ohio, EUA) high intensity reactor/mixer, equipped with an ozone compressing system (ozone cart). After each stage, we extracted residual liquor by pulp centrifugation. We then exhaustively washed the pulp with distilled water before adjusting its consistency for the next stage. We combined equal volumes of residual liquor from each bleaching stage to produce 100 L of each effluent, since all stages ran at the same consistency (10%). ECF and TCF effluents were divided into 5-L aliquots and stored at -20°C until use as feed for the bench-scale activated sludge system.

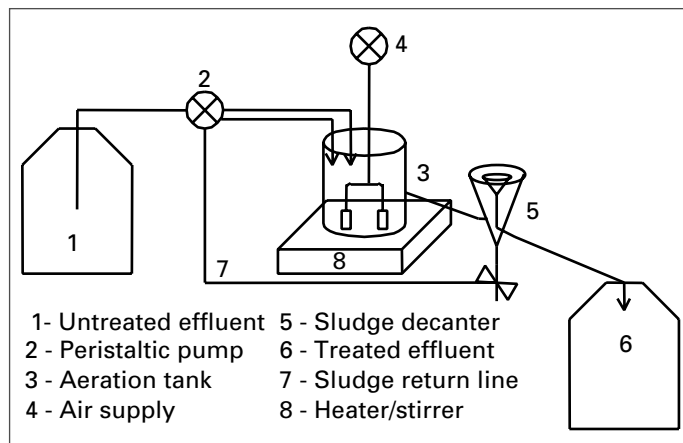
SEQUENCE STAGE	ECF				TCF			
	D	(EO)	D	D	Q	(OP)	(ZQ)	(PO)
Temperature, °C	70	90	70	70	70	100	70/amb.	100
Time, min	30	15+60	180	120	60	60	60	120
Final pH	3	10-11	3.5-4	4-5	7	11	2.5/7	10.5-11
Oven dried pulp, g.	200	150	200	200	200	300	250/200	300
Consistency, %	10	10	10	10	10	10	10	10
REAGENTS, % O.D. PULP BASIS								
ClO ₂	1.0	—	0.8	0.2	—	—	—	—
O ₂	—	0.4	—	—	—	0.4	—	0.2
O ₃	—	—	—	—	—	—	0.4	—
NaOH	—	1.5	—	—	—	1.5	—	1.3
H ₂ O ₂	—	—	—	—	—	1.0	—	3.0
DTPA	—	—	—	—	0.2	—	0.1	—
MgSO ₄ ·7H ₂ O	—	—	—	—	—	0.2	—	0.2

I. Conditions used in ECF and TCF bleaching of oxygen-delignified eucalypt kraft pulp to produce effluents.

Activated sludge system

The bench-scale system simulated activated sludge effluent treatment (**Fig. 1**) [11]. The aeration tank had a working volume of 750 mL. A constant air supply and magnetic stirrer guaranteed complete mixture of the effluent and sludge microorganisms. To feed the activated sludge reactor, we supplemented 5 L of thawed aliquots with nitrogen [(NH₄)₂SO₄] and phosphorous (K₂HPO₄), in the relation BOD:N:P 100:5:1, according to industrial practice [12]. We used the ECF effluent without further adjustment, whereas TCF effluent was neutralized (pH 6 to 8) with H₂SO₄ before entering the reactor. We kept the supplemented and neutralized effluent in a cooler with ice to minimize possible chemical modifications during the 5 to 6 days it took to use up each aliquot. Possible modifications during this period were checked by quantifying COD on the last day of use of the 5 L aliquot. A peristaltic pump fed untreated effluent to the tank. After passing through the tank, the effluent flowed to a decanter with a 500 mL total volume, where effluent and sludge were separated. Clarified effluent exited the decanter through an adjustable funnel placed in its center, which permitted control of the level of effluent in the system. We returned part of the decanted sludge to the aeration tank using the peristaltic pump. Initial inoculation of the aeration tank used sludge from the treatment plant of a Brazilian bleached eucalypt kraft mill.

System stability was evaluated by analyzing COD of effluent exiting the decanter and volatile suspended solids (VSS) within the aeration tank two to three times a week (**Table II**). The system was considered stable, and effluent and sludge sampling started, when the values of these parameters remained constant ($\pm 10\%$) for three consecutive analyses. We took treated effluent and activated sludge samples from the system every 7 to 10 days over a six-week period of treatment of each effluent type. A hot plate kept the aeration tank temperature at 30°C. We maintained an effluent flow of 1 L per day, corresponding to a hydraulic retention time of 18 hours, and adjusted sludge recycling to maintain the food-to-mass ratio (BOD/VSS/d) at about 0.1, conditions typical of an extended aeration system [13].



1. Bench-scale activated sludge treatment system.

Pulp and effluent characterization

We characterized bleached pulps by analyzing viscosity and brightness according to TAPPI procedures (**Table II**). ECF and TCF effluents were characterized before and after treatment by quantifying BOD, COD, AOX and color according to APHA, CPPA or SCAN methods (**Table II**). We repeated all effluent analyses during each evaluation. Effluent biological activity was evaluated by quantifying Microtox toxicity (Microbics, 1992) and chronic toxicity in an algal biomass growth assay [14] (**Table II**). Microtox results were expressed as EC50, the effluent concentration that reduced bacterial viability by 50%. Chronic toxicity was expressed as IC25, the effluent concentration that reduced the algal growth rate by 25%. We obtained a culture of the unicellular green algae *Selenastrum capricornutum* from the Environmental Technology and Sanitation Company of São Paulo and maintained it according to standard procedure [14].

Effluent fractionation and molecular mass distribution profiles

We fractionated untreated and treated effluents by molecular mass (MM) in an Amicon model CH2PR concentrator, using a Diaflo HP3-20 filter with a 3000 Da molecular weight cutoff (MWCO), and then in an Amicon model 8400 ultrafiltration cell,

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PARAMETER	METHOD	REFERENCE
Pulp analysis		
Kappa number	TAPPIT 236 om-85	(15)
Viscosity, mPa.s	TAPPIT230 om 82	(15)
Brightness, %ISO	TAPPIT525 om 86	(15)
Effluent analysis		
BOD, mg/L	APHA 5210c	(16)
COD, mg/L	APHA 5230	(16)
AOX, mg/L	SCAN-W9:89	(17)
Color, mg/L	CPPA H.5P	(18)
Acute toxicity, EC50 %	Microtox 90% Assay	(19)
Chronic toxicity, IC25 %	CETESB L5.020	(14)
Sludge analysis		
VSS, mg/L	APHA 2540	(16)

II. Methods and references for pulp, effluent and sludge characterization .

COMPOUND	SOURCE	NOMINAL MM (Da)
Dextran blue	Sigma	2,000,000
Lysozyme	Sigma	14,400
Aprotinin	Sigma	6512
Commercial tannic acid	Sciavico Comércio e Ind., Ltda. (Brazil)	1700
Rifampicin	Sigma	823
Thiozoyyl blue (MTT)	Sigma	414.3

III. Compounds used as molecular mass (MM) standards for calibration of the molecular exclusion gel chromatography column .

PARAMETER	ECF PULP	TCF PULP
Brightness, %ISO	88.0	87.2
Viscosity, mPa.s	21.6	9.9

IV. Characterization of ECF and TCF bleached eucalypt kraft pulps.

using a YC05 membrane with a 500 Da MWCO. The three fractions obtained (MM <500 Da, 500-3000 Da MM, and MM >3000 Da) were reconstituted to their original volumes with deionized water for subsequent characterization of environmental parameters.

We obtained molecular mass distribution profiles of effluent organic matter by molecular exclusion gel chromatography, according to the method of Pellinen & Salkinoja-Salonen [20], using a Pharmacia C16/20 column with Sephadex 50 gel, attached to an ISCO Retriever 500 fraction collector. Organic matter was eluted with 0.1 m NaNO₃, pH 8.8; at a flow rate of 1 mL/min and eluted fractions were measured at 280 nm in an ISCO UA-6 detector. **Table III** lists organic

compounds used as standards to calibrate the column.

RESULTS AND DISCUSSION

Pulp and effluent characterization

Table IV shows the characteristics of the eucalypt oxygen-delignified kraft pulp bleached by ECF and TCF sequences. Bleaching reagents used in the TCF sequence (O₃, H₂O₂) were less selective towards residual lignin than the ClO₂ used in the ECF sequence. To produce pulps of similar brightness levels, the cellulose fraction of the TCF bleached pulp was more highly degraded than that of the ECF bleached pulp, as reflected by the low viscosity value of the TCF pulp (**Table IV**).

ECF and TCF effluent environmental parameter values (**Table V**) were typical of those of bleached hardwood kraft pulps, as cited by Springer [12]. The greater degradation of the TCF pulp resulted in the production of an effluent richer in organic matter with 3.5-fold more BOD and 2.4-fold more COD than

the ECF effluent. However, effluent BOD/COD values showed that dissolved organic matter in TCF effluent was in a more biodegradable form than in ECF effluent. Although TCF effluent contained more dissolved organic matter, it was less colored than ECF effluent, probably because of the action of residual reagents (ex. H₂O₂) in the TCF effluent. As expected, TCF effluent presented an AOX 60-fold lower than ECF effluent. ECF effluent exhibited both greater Microtox toxicity and algal growth inhibition toxicity than TCF effluent.

Effluent treatment efficiency

BOD reduction during ECF effluent treatment was greater than 97% during the six week evaluation period (**Table VI**). At the same time, removal of COD varied from 47 to 70% and of AOX from 21% to 48%, while effluent color increased from 15% to 65% (**Table VI**). The lowest COD and AOX removals and greatest color increase occurred on the 31st day of treatment. ECF effluent Microtox toxicity was eliminated, whereas chronic toxicity to algae was reduced by treatment, but not removed. The variations in toxicity values have no apparent relationship to the other parameters measured.

BOD removal from TCF effluent was also greater than 97% during the six-week period of evaluation (**Table VII**). COD removal was always greater than 77% (**Table VII**), higher than in ECF effluent (**Table VI**). However, because of the high values of BOD and COD in the untreated TCF effluent (**Table V**), BOD and COD values were higher in the treated TCF effluent than the treated ECF effluent. Color increased only slightly during treatment of TCF effluent (-1 to 8%). TCF effluent acute Microtox toxicity was eliminated while chronic toxicity to algae was reduced during treatment, but not removed (**Table VII**). Toxicity values were not related to the other parameters evaluated.

The levels of BOD and COD removal from ECF (**Table VI**) and TCF (**Table VII**) effluents are comparable to those obtained in high performance activated sludge systems [12]. Measured effluent environmental parameters were consistently below the typical limits established for Brazilian bleached kraft pulp mills. It has been observed that the change from ECF to TCF bleaching does not necessarily affect the operation or

efficiency of the activated sludge treatment process, but treatment may result in greater removal of COD and BOD from TCF effluent than from ECF effluent [1]. The reported [21] deleterious effect of TCF bleaching reagents (H_2O_2 and DTPA) to sludge microorganisms, which purportedly results in lower BOD removal in TCF effluent than in ECF effluent, was not seen in this study. That is probably because these reagents were below the threshold levels necessary to exert effects [22]. TCF treatment efficiency showed greater stability than ECF treatment efficiency. Although BOD removal was consistently high, reduced removals of COD and AOX together with a greater increase in color occurred on day 31 of ECF effluent treatment. We found no explanation for this reduced efficiency since we found no differences in sludge characteristics on this sampling day (data not shown).

Elimination of acute toxicity and similar levels of chronic toxicity in treated ECF and TCF effluents (Tables VI and VII), which were not correlated to levels of dissolved organic matter (BOD, COD, or AOX), suggest that biological activity of treated effluents is not related to the type of bleaching sequence used. That corroborates the conclusions reached by Tana & Lehtinen [4]. It is quite probable that effluent color, which impedes light penetration, caused the algal toxicity by reducing photosynthesis. Mills should, however, conduct toxicity identification evaluations to pinpoint the source of toxicity in each type of bleaching effluent in order to efficiently reduce environmental risks.

Molecular mass distribution of organic matter in effluents

The differences detected in removal of the dissolved organic

PARAMETER	ECF EFFLUENT	TCF EFFLUENT
BOD, mg/L	207	738
COD, mg/L	515	1246
BOD/COD	0.40	0.59
Color, mg/L	400	307
AOX, mg/L	13.11	0.22
pH	6.0	10.0
Acute toxicity, EC ₅₀ ¹ , %	32.0	73.7
Chronic toxicity, IC ₂₅ ² , %	0.8	5.1

¹ EC₅₀ = concentration which reduced bacterial viability by 50% in the Microtox system.
² IC₂₅ = concentration which reduced algal growth rate by 25%.

V. Characterization of laboratory produced ECF and TCF effluents.

matter in TCF and ECF effluents (i.e. greater BOD/COD ratio) are reflected in the molecular mass (MM) distributions of the dissolved organic matter in TCF and ECF effluents before and after treatment (Fig. 2). The organic matter removed from TCF pulp was less degraded before its dissolution than that removed from ECF pulp. Considerable loss of high molecular mass (HMM) organic matter in TCF effluent did occur during treatment, as evidenced by disappearance of the peak with MM >10,000 Da from treated TCF effluent. It is not yet clear if degradation or sorption onto biomass removed this material. We saw little alteration in the MM distribution of the organic matter dissolved in ECF effluent after treatment (Fig. 2). The relatively smaller portion of organic matter with MM >10,000 Da in ECF

DAY	BOD		COD		COLOR		AOX		ACUTE TOXICITY, EC ₅₀ , %	CHRONIC TOXICITY, IC ₂₅ , %
	mg/L	% REDN.	mg/L	% REDN.	mg/L	% REDN.	mg/L	% REDN.		
9	na ¹	—	211	59	547	-37	na ¹	—	na ¹	na ¹
13	na ¹	—	156	70	492	-23	3.20	48	na ¹	na ¹
17	6	97	188	64	483	-21	na ¹	—	na ¹	na ¹
23	5	98	185	64	517	-29	4.29	30	>100	19.5
27	na ¹	—	165	68	459	-15	3.76	39	na ¹	na ¹
31	5	97	273	47	661	-65	4.84	21	>100	20.8
40	5	97	159	69	na ¹	—	4.20	31	>100	8.0
Avg.	5	97	191	63	526	-32	4.06	34	>100	16.1
C.V. ²	8.4	—	21.5	—	13.8	—	15.1	—	—	—

¹na = not analyzed. ²C.V. = coefficient of variation, %.

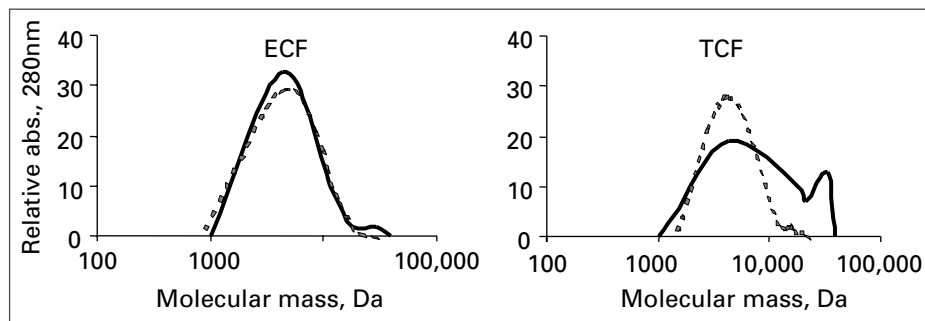
VI. ECF effluent characteristics after treatment in a bench-scale activated sludge system.

DAY	BOD		COD		COLOR		ACUTE TOXICITY, EC ₅₀ , %	CHRONIC TOXICITY, IC ₂₅ , %
	mg/L	% REDN.	mg/L	% REDN.	mg/L	% REDN.		
20	21	97	238	81	323	-5	>100	8.2
26	18	98	179	86	326	-6	na ¹	na ¹
32	16	98	285	77	326	-6	>100	23.3
41	16	98	245	80	330	-8	>100	20.7
50	16	98	210	83	305	1	na ¹	na ¹
Avg.	16	98	236	81	322	-5	>100	17.4
C.V. ²	14.1	—	15.2	—	3.0	—	—	—

¹na = not analyzed. ²C.V. = coefficient of variation, %.

VII. TCF effluent characteristics after treatment in a bench-scale activated sludge system.

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2. Molecular mass distribution profiles of dissolved organic matter in original (- - -) and biologically treated (—) ECF and TCF effluents, determined by gel permeation chromatography.

effluent proved more refractory to biological treatment than the HMM matter in TCF effluent. Chemical characterization of organic matter dissolved in ECF and TCF effluents has shown that HMM (>1000 Da) matter in TCF bleaching effluents contains more carbohydrates, principally xylans, than that in ECF effluents [8]. HMM (>1000 Da) matter in ECF effluents contains few aromatic structures, but originates principally from degradation of lignin phenolic structures [8]. The nature of the organic matter dissolved in bleaching effluents affects its biodegradability during activated sludge treatment. COD removal in effluents with higher levels of carbohydrates is more complete than COD removal in effluents with higher levels of residual lignin [23],

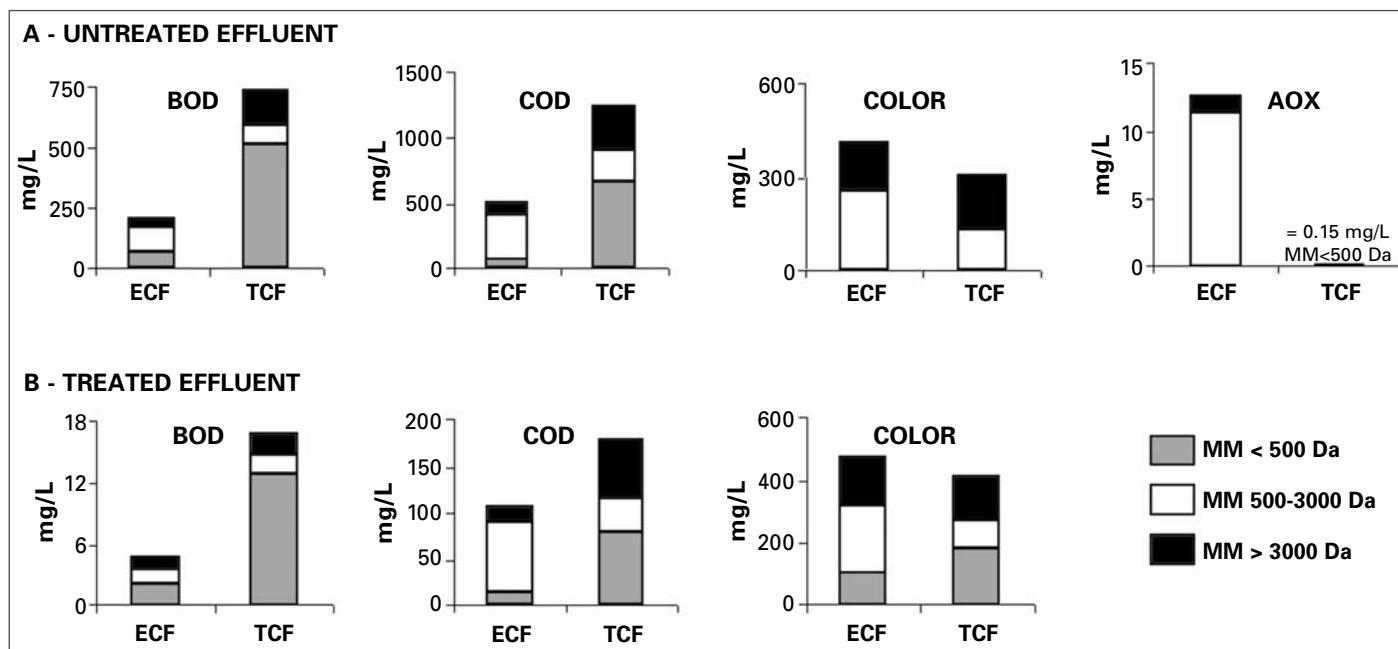
which may explain the high COD removal from the TCF effluent. The results obtained in this study indicate that the concentration of HMM matter does not necessarily increase after biological treatment because of poorer biological removal of this material as previously found for chlorine-containing bleaching effluents [7-10, 24].

Influence of molecular mass on effluent treatability

We learned more about the influence of molecular mass on removal of dissolved organic matter by evaluating the relative contributions of three effluent fractions, separated by ultrafiltration using membranes with 3000 Da and 500 Da MWCOs, to untreated and treated ECF and TCF effluent BOD, COD, AOX and

color values (Fig. 3). The ECF effluent fraction with MM between 500 and 3000 Da showed the largest contribution to untreated effluent BOD, COD, AOX and color (Fig. 3A). In contrast, the corresponding TCF effluent fraction (MM between 500 and 3000 Da) showed the smallest contribution to untreated TCF effluent BOD and COD (Fig. 3A). The greatest contribution to untreated TCF effluent BOD and COD came from the fraction with MM <500 Da and to color from the fraction with MM >3000 Da. The fraction with MM <500 Da contained virtually all of the TCF effluent AOX, which may have arisen from natural wood contamination.

The contribution of the three fractions to effluent color changed the most after treatment of both ECF and TCF effluents (Fig. 3B). The proportion of color in the fractions with MM between 500 and 3000 Da and >3000 Da decreased after treatment, with a new contribution arising from the fraction with MM <500 Da. The relatively small increase in TCF effluent color after treatment (Table VII) may relate to the high COD removal in this effluent, resulting in fewer remaining intermediate chromophores, as suggested by Dahlman et al. [8]. The greater increase in ECF effluent color after treatment (Table VI) prob-



3. Contributions of different molecular mass fractions to BOD, COD, AOX and color of A - untreated and B - biologically treated ECF and TCF effluents.

ably reflects the lesser degradation of HMM organic matter in this effluent, particularly that with MM between 500 and 3000 Da (Figs. 2 and 3).

Molecular mass is not necessarily the limiting factor for removal of certain recalcitrant compounds, particularly organochlorine compounds [25] that may contain chemical structures uncommon in nature. The ECF effluent fraction with the largest proportion of AOX (MM between 500 and 3000 Da) was also the fraction responsible for the largest part of ECF effluent COD (Figure 3A). Its contribution to COD even increased after treatment (Fig. 3B), suggesting the presence of recalcitrant organochlorine structures. We also noted this is the distribution of color containing compounds before and after treatment (Figs. 3A and B). Compounds with MM between 500 and 3000 Da were the main cause of ECF effluent color, both before and after treatment. In TCF effluent, we found more color in compounds with MM <500 Da, indicating a greater degradation of compounds with MM between 500 and 3000 Da.

CONCLUSIONS

Based on the results obtained in this study, we concluded that:

- TCF bleaching produces effluent richer in dissolved organic matter than ECF bleaching of eucalypt kraft pulp when bleaching to similar brightness levels.
- TCF effluent contains more high molecular mass organic matter than ECF effluent, but this matter is more efficiently removed during biological treatment, resulting in greater removal of COD from TCF than from ECF effluent.
- Untreated ECF effluent presents higher levels of Microtox toxicity and chronic toxicity to algae than untreated TCF effluent produced from the same eucalypt kraft pulp.
- Biologically treated ECF and TCF effluents produced from the same eucalypt kraft pulp present no Microtox toxicity and similar levels of chronic toxicity to algae.

Further studies should identify the microorganisms responsible for biodegradation of recalcitrant COD and how to optimize their activity during the biological treatment process. **TJ**

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LITERATURE CITED

1. Saunamäki, R., *Tappi J.*, 78(8): 185(1995).
2. Cates, D. H., Eggert, C., Yang, J. L. and Eriksson, K-E. L., *Tappi J.*, 78(12): 93(1995).
3. Stauber, J., Gunthorpe, G., Woodworth, J., Munday, B., Krassoi, R. and Simon, J., *Appita* 49(3): 184(1996).
4. Tana, J. and Lehtinen, K-J., *The Aquatic Environmental Impact of Pulping and Bleaching Operations – An Overview*, Finnish Environment Institute, Helsinki, 1996, 103 pp.
5. Liss, S. N. and Allen, D. G., *J. Pulp Paper Sci.* 18(6): J216(1992).
6. Buitrón, G. and González, A., *Wat. Sci. Tech.* 34(5-6): 289 (1996).
7. Bryant, C. W., Avenell, J. J., Barkley, W. A. and Thut, R. N., *Wat. Sci. Tech.* 26(1-2): 417(1992).
8. Dahlman, O., Reimann, A. K., Stomberg, L. M. and Mörrck, R. E., *Tappi J.*, 78(12): 99(1995).
9. Martin, V. J. J., Burnison, B. K., Lee, H. and Hewitt, M., *Holzforchung* 49(5): 453(1995).
10. Sonnenberg, L. B., Wimer, P. and Ard, T. A., "Transformations of wastewater during biological treatment," in: TAPPI 1995 International Environmental Conference, TAPPI Press, Atlanta 1995, p.219 – 231.
11. Diez, M. C., Inostroza, L. and Ramirez, S., *Biotech. Lett.* 18(2): 187(1996).
12. Springer, A. M. *Industrial Environmental Control – Pulp and Paper Industry*, 2 edn., TAPPI Press, Atlanta, 1993, 699p.
13. Bitton, G., *Wastewater Microbiology*, Wiley Liss, New York, 1994, 478p.
14. Companhia de Tecnologia de Saneamento Ambiental de São Paulo, *Teste de toxicidade com Chlorella vulgaris*. Norma L5.020, CETESB, São Paulo, dez/1986.
15. Technical Association of the American Pulp and Paper Industry, *Test Methods*. TAPPI Press, Atlanta, 1988.
16. Eaton, A. D., Clesceri, L. S. and Greenberg, A. E. (Eds.), *Standard Methods for the Examination of Water and Wastewater*, 19 edn., American Public Health Association, Washington, 1995.
17. Scandinavian Pulp, Paper and Board Testing Committee, *Test Methods*, SCAN, Stockholm, 1989.
18. Canadian Pulp and Paper Association, *Technical Section Standard Test Methods*, CPPA, Montreal, 1986.
19. Microbics Corp. *Microtox Manual*, Carlsbad, 199., 5 v.
20. Pellinen, J. and Salkinoja-Solonen, M., *J. Chromatography* 322: 129(1985).
21. Larisch, B. C. and Duff, S. J. B., *Wat. Sci. Tech.* 35(2-3): 163(1997).
22. Larisch, B. C. and Duff, S. J. B., Effect of DTPA and EDTA activated sludge reactors treating bleached kraft mill effluent., In: TAPPI 1999 International Environmental Conference, Tappi Press, Atlanta, 1999, p. 401-413.
23. Herstad-Svård, S., Basta, J., Jour, P. and Wäne, G., Caracterização comparativa dos efluentes de modernas plantas de branqueamento (ECF) – celulose de eucalyptus e de fibra longa., 30º Congresso Anual de Celulose e Papel, 1997, São Paulo, ABTCP, p.49-62.
24. Herstad-Svård, S., Jour, P., Basta, J., Basta, J. and Aggarwal, P., "Increasing the biotreatability of ECF bleaching effluents by ultrafiltration and partial closure of alkaline filtrates," In: TAPPI 1999 International Environmental Conference, TAPPI Press, Atlanta, 1999, p. 319-331.
25. Jokela, J. K., Laine, M., Ek, M. and Salkinoja-Solonen, M., *Environ. Sci. Technol.* 27(3): 547(1993).

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INSIGHTS FROM THE AUTHORS

We chose this topic to research because little information exists in the literature on treatment of Brazilian eucalypt bleaching effluents, and much conflicting information exists on the virtues of ECF versus TCF bleaching.

The study itself is part of a broader study on microbiological characterization of activated sludge systems and the impact of changing effluent composition. Differences encountered in this study can be directly related to bleaching processes, since raw material used for bleaching was virtually the same. That is never the case for mill studies, nor most comparative lab studies. It is clear that under controlled laboratory conditions, environmental quality of biologically treated eucalypt ECF and TCF bleaching effluents is quite similar.

The only significant problem encountered in this study was the operation of the bench-scale system with effluents of such different BOD and COD levels. We overcame that by adapting the activated sludge to each effluent. One surprise from the results was the large difference in quantity and

removal of high molecular mass components of TCF effluents as compared to ECF effluents. That suggests that significant microbiological diversity exists in the activated sludge.

Since completing this study, we have begun to investigate ways to improve the microbiological removal of the recalcitrant high molecular mass COD in eucalypt ECF effluents.

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Colodette



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