

Decreased water usage in a softwood ECF bleaching sequence—full mill simulations

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ABSTRACT: In this study, an elemental chlorine free (ECF) bleach plant with a $D_0(EOP)D_1(EP)D_2$ sequence was studied with the aim of identifying options for significantly decreasing (fresh) water usage in the bleach plant and decreasing the effluent volume. A base-case simulation model for a softwood kraft market pulp mill was made based on a reference model representing the best available techniques as well as data produced in an extensive laboratory pulp bleaching study. This model was used to evaluate increased closure within the bleach plant and the recirculation of bleach plant effluent to the brownstock system and their effects on both the bleach plant and the recovery cycle. The results indicate that it is possible to reduce the fresh water consumption from 15 metric tons/a.d. metric ton in the base case to about 2 metric tons/a.d. metric ton, without increasing the carryover of chemical oxygen demand (COD) to the pulp machine.

Nonprocess elements in wood contribute to the levels of metals found in the bleach plant and thus to the risk of precipitates such as calcium oxalate, barium sulfate, and calcium carbonate. The risk of precipitates forming is a key factor determining the possible degree of closure. In addition, chloride concentration in the black liquor is another important factor that is affected by recirculating bleach plant filtrate to the brownstock washer and by the grade of the sodium hydroxide used in the mill.

Application: The intention of this work is to give input for possible steps that can be taken in order to reduce the water use in a pulp mill applying ECF bleaching technology.

Water is an important natural resource and reducing water consumption in the pulp industry is a key factor in achieving sustainable pulp production. With a growing world population and the increasing scarcity of fresh water in certain parts of the world, the need for the industry to reduce its “water footprint” is accentuated. In this study, an elemental chlorine free (ECF) bleach plant with a $D_0(EOP)D_1(EP)D_2$ sequence was studied with the aim of identifying options for significantly decreasing (fresh) water usage in the bleach plant and thereby decreasing the volume of effluent emitted to the recipient.

During the mid-1990s, pulp mill closure was already an area of focus, both among researchers as well as in the industry. In general, the work was targeting reduced effluent volumes and chemical oxygen demand (COD) discharge from the pulp mill, including partial closure solutions. This work builds on previous work and adds information about scale deposits [1-3].

EXPERIMENTAL

A base-case simulation model for a softwood kraft pulp mill was developed in the WinGEMS process simulator (Valmet; Espoo, Finland) based on a reference model representing the best available technology for a softwood kraft pulp mill developed by RISE Bioeconomy, formerly Innventia [4]. The simulation program was equipped with an extension tool that han-

dles the chemical model used for determining the equilibrium composition in the fiber line. The chemical equilibrium calculations were based on minimizing Gibbs free energy and include the metal interactions with the pulp as well as with the dissolved organic material.

Some of the chemical formation constants of the main chemical species formed can be found in the chemical literature, but in many cases, the chemical conditions found in a pulp mill and a bleach plant are highly specific, with no applicable data being available in the literature. Accordingly, an extensive series of measurements were performed at RISE Bioeconomy [5-9] to determine these formation constants and to formulate the chemical model describing the system under the technical conditions found in a kraft pulp mill. This makes it possible to predict the formation of scaling—calcium oxalate, barium sulfate, and calcium carbonate—at different positions in the fiber line.

The model mill with the $D_0(EOP)D_1(EP)D_2$ bleaching sequence was equipped with vacuum filters in both the brownstock and the bleach plant. The last washer before the bleach plant was a wash press. The dilution factor for the washers used in the bleach plant was 2.4–2.5 metric tons/a.d. metric ton.

Supplementary data produced in a laboratory bleaching study was also included in the model. The bleaching experiments were carried out on an industrial oxygen delignified softwood kraft pulp, from a southern U.S. mill, with a kappa

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number of 12.4 and brightness of 39% ISO. The bleaching stages were performed in polyethylene bags in water baths, and the pressurized stages were performed in steel autoclaves. The metal content was measured in the washed pulps before entering each bleaching stage in the sequence. The content of metals was also, together with chlorides (Cl⁻), measured in the softwood (southern pine) raw material used in this study. The COD, carbonate, and oxalate contents were analyzed in the filtrates from the individual bleaching stages.

ISO brightness and kappa number were analyzed according to ISO 2470-1:2016 “Paper, board and pulps—Measurement of diffuse blue reflectance factor—Part 1: Indoor daylight conditions (ISO brightness)” and ISO 302:2015 “Pulps—Determination of Kappa number”, respectively. The COD was analyzed according to the Dr. Lange Cuvette Test Method with a Hach Lange DR 2800 instrument (Hach Lange; Berlin, Germany). Ion chromatography was used to analyze oxalate after pre-treating the sample with nitric acid and heat. Carbonate was analyzed as inorganic carbon using a Shimadzu TOC-VCPH instrument (Shimadzu; Kyoto, Japan); metal content was determined following acid digestion using nitric acid, hydrogen peroxide (H₂O₂), and hydrochloric acid with an inductively coupled plasma instrument (iCAP 6500 Duo, Thermo; Cambridge, U.K.); and chloride was analyzed by capillary ion electrophoresis with a Model 7100 Capillary Electrophoresis (CE) System (Agilent Technologies; Santa

Clara, CA, USA) after combustion in an oxygen bomb (Model 1108 Oxygen Combustion Bomb, Parr Instrument Company; Moline, IL, USA).

RESULTS AND DISCUSSION

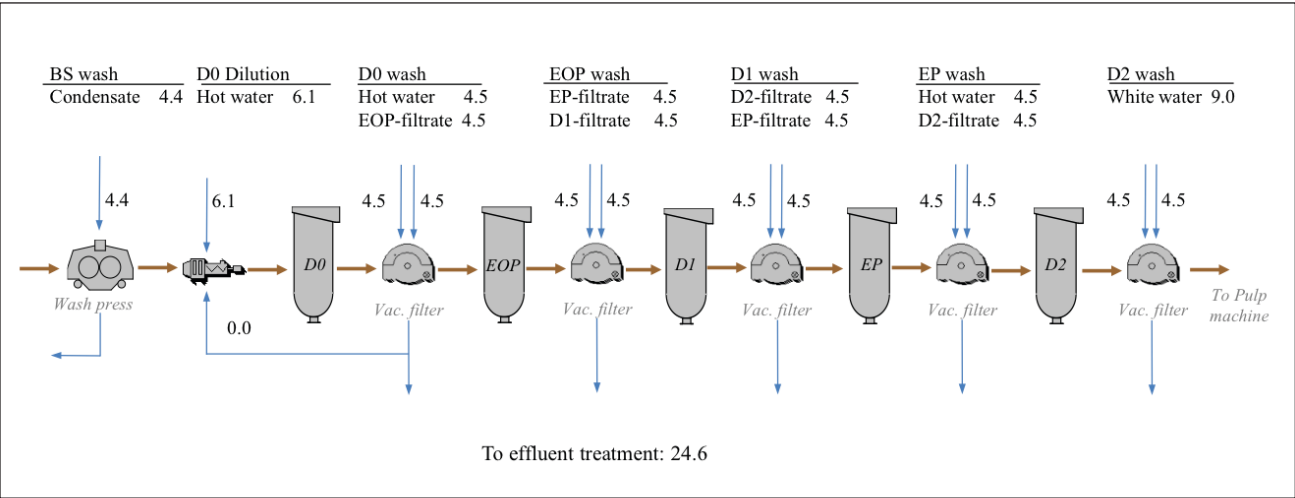
Nonprocess elements (NPEs) content in wood significantly affects the levels in the pulp entering the bleach plant. The calcium and barium content contribute to the risk of formation of precipitates such as calcium oxalate, barium sulfate, and calcium carbonate. Chloride content is important for levels present in the recovery area. Nonprocess elements content (mg/kg dry solids) in the wood used in the simulations were: barium (Ba), 69; calcium (Ca), 646; potassium (K), 388; magnesium (Mg), 182; manganese (Mn), 75; and chlorine (Cl), 42. The formation of COD, carbonate and oxalate used in the model are based on the results from the laboratory study and presented in **Table I**.

Base case (case A1)

The base case, A1, adopts a fairly open washing strategy with no bleach plant filtrate being recycled to the brownstock washer. The washing strategy used in the bleach plant can be seen in **Fig. 1**. White water from the drying machine was used on the vacuum filter after the D₂ stage. D₂ filtrate was used in equal shares for washing on the (EP) and D₁ filters. Hot water was used together with the D₂ filtrate for washing

	D ₀	(EOP)	D ₁	(EP)	D ₂	Total
COD, kg/a.d. metric ton	7.7	11.3	3.1	2.3	1.0	25.4
Carbonate, kg/a.d. metric ton	0	2.19	0	0.60	0	2.79
Oxalate, kg/a.d. metric ton	0.49	0.27	0.15	0.06	0.04	1.01

I. Chemical oxygen demand (COD), carbonate, and oxalate formed in the different stages in the D₀(EOP)D₁(EP)D₂ bleaching sequence used in the WinGEMS simulation.



1. Washing strategy used for the base case, A1. The flows are given as metric tons/a.d. metric ton. The total effluent consists of D₀ filtrate 11.9, (EOP) filtrate 4.6, D₁ filtrate 5.4, condensate 0.4, and white water 2.3 metric tons/a.d. metric ton (BS = brownstock).

	D ₀	(EOP)	D ₁	(EP)	D ₂	Total
Chlorine dioxide, kg aCl/a.d. metric ton	27.1	-	15.4	-	3.6	46.1
Hydrogen peroxide, kg/a.d. metric ton	-	1.8	-	0.9	-	2.7
Sulfuric acid, kg/a.d. metric ton	2.8	-	-	-	0.1	2.9
Sodium hydroxide, kg/a.d. metric ton	-	6.5	1.8	2.7	-	11.0
Temp, °C	70	80	70	80	70	-
pH	2.5	~ 11	3.3	~ 11	4.2	-

II. Conditions and chemical charges used in the base case.

	A1
Total effluent volume, metric tons/a.d. metric ton	24.6
White water to effluent, metric tons/a.d. metric ton	2.3
Condensate to effluent, metric tons/a.d. metric ton	0.4
Fresh water to bleach plant, metric tons/a.d. metric ton	15.2
COD to effluent, kg/a.d. metric ton	31.4
COD to pulp machine, kg/a.d. metric ton	1.3
Sodium hydroxide makeup, kg/a.d. metric ton	15.0
Chlorides in black liquor as fired, %	0.26
Total charge of chlorine dioxide, kg aCl/a.d. metric ton	46.1

III. Key data for the base case, A1.

on the (EP) filter. (EP) filtrate was used in equal shares for washing on the D₁ and (EOP) filters. Half of the D₁ filtrate was used for washing on the (EOP) filter and the rest was sent to effluent treatment. A mix of (EOP) filtrate and hot water was used on the vacuum filter after the D₀ stage. The dilution of the pulp prior to the D₀ tower was accomplished using hot water. The dilution of pulp in the other bleaching stages was accomplished through internal dilution. Black liquor condensate was used for washing the pulp on the press prior to the bleach plant (the press is denoted BS [brownstock] wash in **Figs. 1-4**). The remaining condensate was used in the white liquor preparation and a small share was sent to the effluent treatment. The total effluent from the base case consists of D₀ filtrate 11.9, (EOP) filtrate 4.6, D₁ filtrate 5.4, condensate 0.4, and white water 2.3 metric tons/a.d. metric ton.

Apart from the effluent shown in the flow sheet, there was also a minor effluent flow from the pulp machine with reject, corresponding to 0.15 metric ton/a.d. metric ton. This amount was the same in all cases and will henceforth be excluded from all of the effluent figures presented. Apart from the specified D₂ filtrate, there were small amounts available for washing (0.1 metric ton/a.d. metric ton). In the model, these amounts were used in different positions. However, to sim-

plify Figs. 1-4, these amounts have been included in the amount of D₁ filtrate used.

The conditions and charges used in the bleach plant for the base case are listed in **Table II**. The final brightness after bleaching was 89.5%–90% ISO and the carryover of COD to the bleach plant was 9 kg/a.d. metric ton. The total charge of bleaching chemicals used in this case was 46 kg active chlorine (aCl)/a.d. metric ton and 2.7 kg H₂O₂/a.d. metric ton. The chlorine dioxide (ClO₂) charges in the D₀ and D₁ stages were increased due to increased carryover of COD in order to reach the same final brightness in all of the cases compared; a factor of 0.3 kg aCl/kg COD was used. The peroxide charges have been the same regardless of the carryover of COD. The temperature and pH used in the D₀ stage was 70°C and 2.5, respectively, resulting in no calcium oxalate formation being predicted. All conditions except for the charge of chlorine dioxide were kept constant in all of the cases compared.

Calcium carbonate can be formed around the alkaline stages in the bleach plant and is known to require a high degree of supersaturation before it starts to precipitate. If precipitation does occur, this is often on the pulp, and might not therefore impact the runnability of the mill. The levels of calcium carbonate predicted in the base case simulations

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	A1	A2	B1	B2	B3	B4	C1
Total effluent volume, metric tons/a.d. metric ton	24.6	21.9	12.9	10.5	10.5	9.8	11.4
White water to effluent, metric tons/a.d. metric ton	2.3	0	0	0	0	0	0
Condensate to effluent, metric tons/a.d. metric ton	0.4	0	0	0	0	0	0
Fresh water to bleach plant, metric tons/a.d. metric ton	15.2	12.5	3.5	1.1	1.1	0.4	2.1
COD to effluent, kg/a.d. metric ton	31.4	31.5	30.3	25.6	25.6	24.6	26.0
COD to pulp machine, kg/a.d. metric ton	1.3	1.3	2.2	2.2	2.2	2.2	1.4
Sodium hydroxide makeup, kg/a.d. metric ton	15.0	15.0	15.0	13.2	13.2	12.7	13.0
Chlorides in black liquor as fired, %	0.26	0.26	0.26	1.03	0.82	1.02	1.01
Total charge of chlorine dioxide, kg aCl/a.d. metric ton	46.1	46.1	46.4	47.5	47.5	47.8	47.7

IV. Key parameters for the simulated cases evaluated. Diaphragm sodium hydroxide was used in case A1, A2, B1 and B2 and membrane sodium hydroxide was used in cases B3, B4 and C1.

were considered to be low and not to cause any problems. Barium sulfate formation was indicated only in the D₀ stage, although the amount modelled was also considered low and not to cause any precipitation problems. If a wood source with another composition of NPEs had been used, the risk for precipitation would have been different.

Some key data for the base case can be found in **Table III**. With this fairly open system and sodium hydroxide (NaOH) produced with the diaphragm method, the levels of chloride in the white and black liquors were maintained at acceptable levels, 0.77 g/l and 0.26%, respectively. The fresh water used in the bleach plant, 15.2 metric tons/a.d. metric ton, does not include the water used for diluting chemicals, which ranges from 1.8–1.9 metric tons/a.d. metric ton in all cases compared in this study. The amount of fresh water used on the pulp machine was kept constant at 4.9 metric tons/a.d. metric ton. The purge of precipitator dust in the base case was 14.9 kg/a.d. metric ton. The total effluent flow was 24.6 metric tons/a.d. metric ton containing 31.4 kg COD/a.d. metric ton.

Closure strategies

In this study, three concepts were studied:

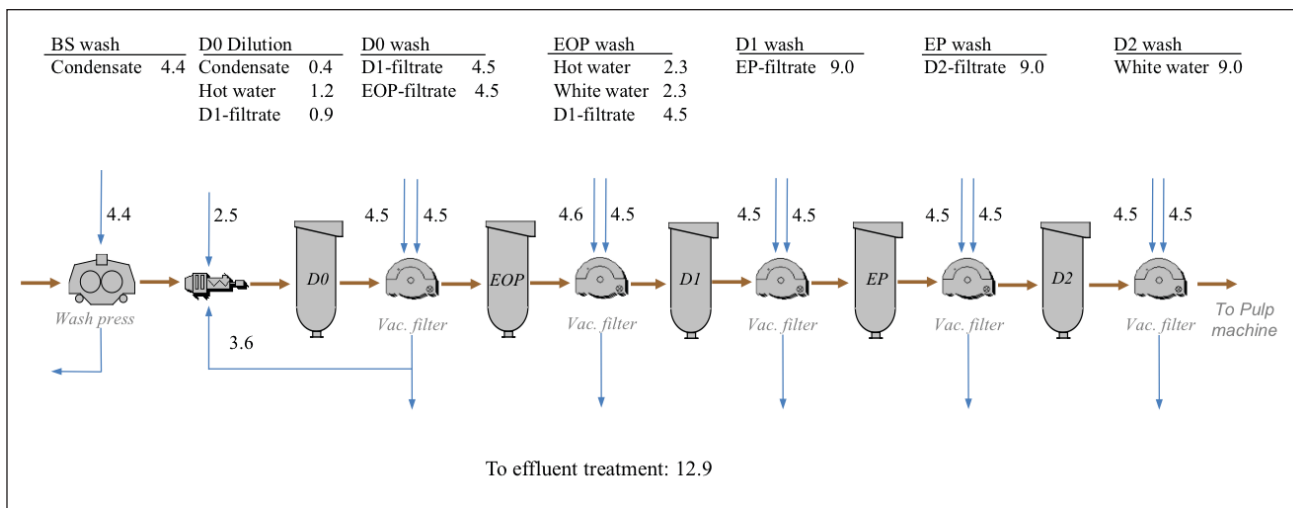
- The first step towards increased closure was to increase the use of white water and condensate (case A2).
- The second concept, denoted B (cases B1–B4), was to use countercurrent washing on the last three washers in the bleach plant (D₁, (EP) and D₂). That is, white water was used for washing after the D₂ stage, D₂ filtrate was used for washing after the (EP) stage, etc.
- The third concept, denoted C (case C1), was to use a

semi-countercurrent washing strategy for the washers in the bleach plant. The last filtrate used for washing is from the following bleaching stage. For example, for the D₁ washer, half of the washing liquor used was D₂ filtrate and the other half was (EP) filtrate.

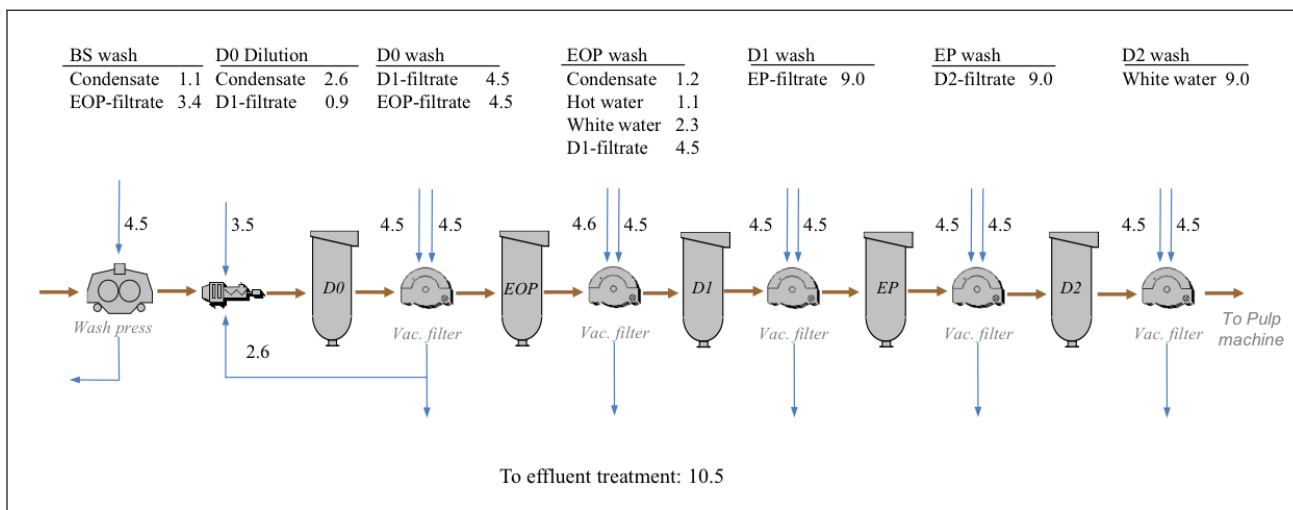
The purpose of the concepts B and C was to increase the use of D₀ and (EOP) filtrates until the limitations for calcium oxalate precipitation and/or chloride content in the black liquor were reached. The D₀ filtrate was used in the D₀ dilution and the (EOP) filtrate was recirculated to the brownstock. This applies for all cases except for case B1 where only the use of D₀ filtrate was maximized. In the studied cases, we have not considered the possible changes in the need for additional charges of acid and alkali in order to reach the pH targets in the bleach plant.

Increased usage of white water and condensate (case A2)

The first step towards increased closure of the base case was to use the remaining white water and condensate, which in the base case was sent to effluent treatment, in the dilution/mixing before the D₀ stage, case A2. This did not impact the risk of scaling or the amounts of chlorides in the white and black liquor since the content of NPEs are low in both streams. The fresh water used in the bleach plant was reduced by 2.7 metric tons/a.d. metric ton and the total effluent was reduced from 24.6 metric tons/a.d. metric ton in the base case to 21.9 metric tons/a.d. metric ton. The key data for case A2 can be found in **Table IV**.



2. Washing strategy for countercurrent concept, B1. The flows are given as metric tons/a.d. metric ton. The total effluent consists of D₀ filtrate 8.1 and (EOP) filtrate of 4.8 metric tons/a.d. metric ton (BS = brownstock).



3. Washing strategy for the countercurrent concept, B2. The flows are given as metric tons/a.d. metric ton. The total effluent consists of D₀ filtrate 9.1 and (EOP) filtrate of 1.4 metric tons/a.d. metric ton (BS = brownstock).

Countercurrent washing (cases B1–B4)

The washing strategy for the first countercurrent case, B1, described in more detail in **Fig. 2**, utilizes D₀ filtrate to the point where calcium oxalate precipitation is about to form in the D₀ tower. The fresh water used in the D₀ dilution for the base case was replaced with a mix of D₀ filtrate, hot water, condensate, and D₁ filtrate. This washing strategy decreases the fresh water used in the bleach plant to 3.5 metric tons/a.d. metric ton and the total effluent to 12.9 metric tons/a.d. metric ton containing 25.6 kg COD/a.d. metric ton.

The next case, B2, utilizes both the (EOP) and D₀ filtrates to the point where calcium oxalate precipitation is about to form and the level of chloride in the black liquor was about 1%. The washing strategy for this case, B2, is described in more detail in **Fig. 3**. In this case it was possible to use 3.4 metric tons of (EOP) filtrate/a.d. metric ton on the last washer before the bleach plant. In the D₀ dilution, a mix of D₀ filtrate,

condensate, and D₁ filtrate is used. This washing strategy decreases the fresh water used in the bleach plant to 1.1 metric tons/a.d. metric ton and the total effluent to 10.5 metric tons/a.d. metric ton containing 25.6 kg COD/a.d. metric ton.

One possibility for further closing up the bleach plant and increasing the use of (EOP) filtrate on the brownstock washer was to improve the quality of the sodium hydroxide used in the mill (makeup to white liquor, oxygen delignification, and bleach plant). The sodium hydroxide produced with the membrane technology has a lower content of chlorides compared to sodium hydroxide produced using the diaphragm method, 0.0064 wt% compared to 0.75 wt%, respectively. This measure reduces the chloride content in the black liquor from 1.04 wt% to 0.82 wt%, case B3, and makes it possible to increase the use of (EOP) filtrate somewhat. Maximizing the use of both D₀ filtrate and the use of (EOP) filtrate makes it

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possible to reach a total fresh water consumption in the bleach plant of 0.4 metric tons/a.d. metric ton and a total effluent volume of 9.8 metric tons/a.d. metric ton, case B4. The key data for cases B1–B4 can be found in Table IV. One drawback using this concept was the increased carryover of COD to the pulp machine, from 1.3 kg COD/a.d. metric ton in the base case to 2.2 kg COD/a.d. metric ton, which might have a negative effect on the final pulp produced. Therefore, another washing concept—semi-countercurrent washing—was also evaluated.

Semi-countercurrent washing (case C1)

A description of the case where the semi-countercurrent washing strategy has been adopted, case C1, can be seen in **Fig. 4**. The filtrates from the D₂ and (EP) stages are divided and used in equal amounts on the two preceding washers. Membrane sodium hydroxide was used in this case and the use of D₀ and (EOP) filtrates was again maximized to the limit for calcium oxalate precipitation in the D₀ stage and the level of chloride in the black liquor to about 1 wt%. The amount of fresh water used in this case was 2.1 metric tons/a.d. metric ton on the (EP) filter. The total effluent was 11.4 metric tons/a.d. metric ton, containing 26.0 kg COD/a.d. metric ton. Using this concept results in a similar carryover of COD to the pulp machine as in the base case. The key data for this case is presented in Table IV.

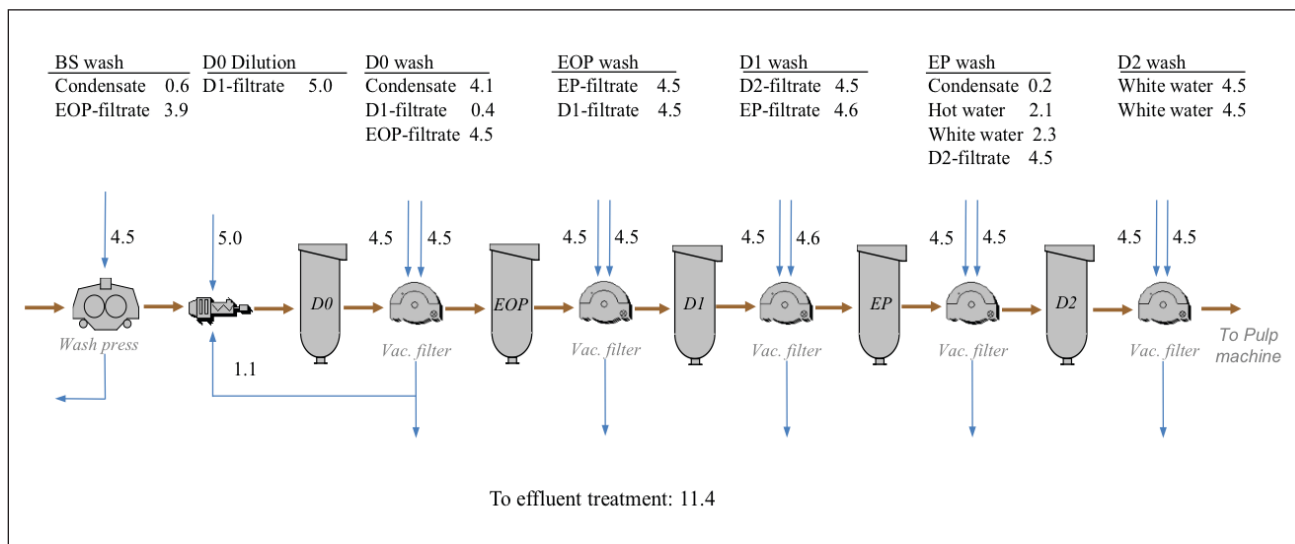
Comparison of the different cases

The key data for all of the cases included in this study are summarized and presented in Table IV. The use of fresh water in the bleach plant could be reduced from 15.2 metric tons/a.d. metric ton in the base case, A1, to 0.4 metric tons/a.d. metric ton, case B4, using the countercurrent washing concept, also including the use of sodium hydroxide produced with the membrane method, with a low content of chlorides.

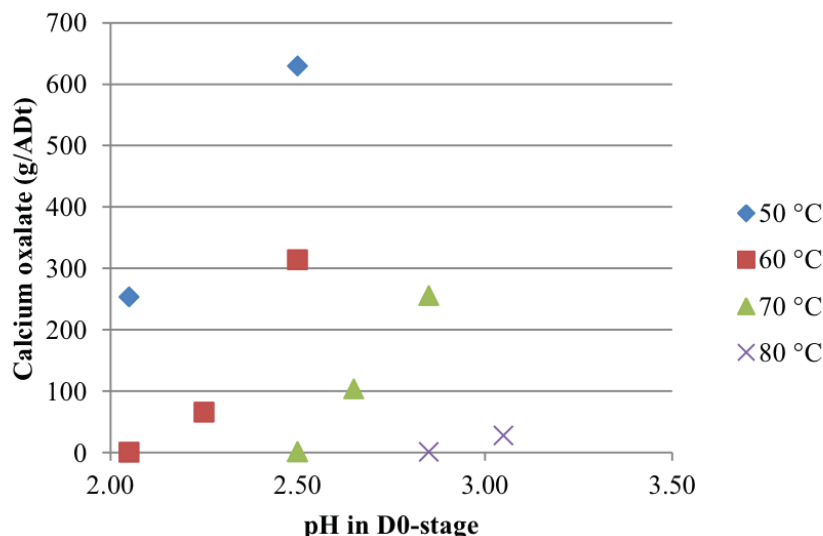
In this case, B4, a total effluent volume of 9.8 metric tons/a.d. metric ton including 24.6 kg COD/a.d. metric ton, could be attained. The drawback of using this concept was the increased carryover of COD to the pulp machine. For case C1, using the semi-countercurrent washing concept, it was possible to keep the carryover of COD to the pulp machine at the same level as in the base case. However, this concept resulted in a need for somewhat higher fresh water use in the bleach plant, 2.1 metric tons/a.d. metric ton, and a total effluent flow of 11.4 metric tons/a.d. metric ton, containing 26.0 kg COD/a.d. metric ton. The net wash loss decreased when more (EOP) filtrate was used for brownstock washing, resulting in a decreased need for sodium hydroxide makeup when closing up the bleach plant.

In all of the cases compared, fresh water to the pulp machine and fresh water for the dilution of chemicals was kept constant at 4.9 metric tons/a.d. metric ton and 1.8–1.9 metric tons/a.d. metric ton, respectively. The potassium content in the black liquor as fired was relatively unaffected by the increased closure, between 1.43%–1.49% for all of the cases evaluated. The sulfidity in the white liquor was kept constant at 35%. The purge of precipitator dust increased somewhat due to the increased closure, from 14.9 kg/a.d. metric ton in the base case, A1, to between 16.2–16.7 kg/a.d. metric ton for the B1–B4 and C1 cases.

In all cases, the degree of closure has been pushed to be on, or just below, the limit for the formation of calcium oxalate. Formation of barium sulfate is predicted in all cases around the D₀ stage, although the levels are low and not expected to cause problems. Calcium carbonate formation is predicted in the alkaline stages, both in the tower and in the filtrate tank, with the highest levels being found in the (EOP) tower. However, since the degree of supersaturation is low in all cases, calcium carbonate precipitation is not expected to have an impact on the runnability of the bleach plant.



4. Washing strategy for the semi-countercurrent washing strategy, C1. The flows are given as metric tons/a.d. metric ton. The total effluent consists of D₀ filtrate 10.6 and (EOP) filtrate of 0.8 metric ton/a.d. metric ton (BS = brownstock).



5. Formation of calcium oxalate in the D_0 stage, at different temperatures and final pH levels.

Effect of temperature and pH in the D_0 stage on formation of calcium oxalate using the semi-countercurrent concept (case C1)

It is well known that increased temperature and/or decreased pH could be applied to decrease the risk of formation of calcium oxalate [7,9]. In this work, the closure has been taken to the limit for when precipitation of calcium oxalate was predicted by the model. The position most sensitive to this was around the D_0 stage, in the bleach tower and filtrate tank.

Using a wood source with a calcium content of 646 mg/kg dry solids and the conditions applied in the D_0 stage in case C1 using the semi-countercurrent washing concept, at 70°C and a final pH of 2.5, it was possible to run the simulation without predicting calcium oxalate formation. A study was performed in order to evaluate different combinations of temperature and pH that could be used in the D_0 stage in order to avoid calcium oxalate formation being predicted when using this concept. The results are presented in **Fig. 5**. As can be seen in the figure, the model indicates that it would be possible to avoid calcium oxalate formation by using either a temperature of 60°C and a final pH of 2.05, a temperature of 70°C and a pH of 2.5, or a temperature of 80°C and a pH of 2.85.

CONCLUSIONS

The WinGEMS simulation of a mill producing ECF bleached softwood kraft pulp indicates that it is possible to significantly reduce the amount of fresh water used in the bleach plant. In this work, three main concepts were studied to reduce the use of fresh water. The first step towards increased closure was to use all available white water and condensate in the bleach plant. The next step was to introduce countercurrent washing and increase the internal use of D_0 filtrate, resulting in a fresh water consumption of 3.5 metric tons/a.d. metric

ton and an effluent flow of 12.9 metric tons/a.d. metric ton.

By using a countercurrent washing strategy and sodium hydroxide produced by the membrane process, it was possible to achieve a fresh water consumption in the bleach plant of 0.4 metric tons/a.d. metric ton and an effluent flow of 9.8 metric tons/a.d. metric ton, containing 24.6 kg COD/a.d. metric ton. However, the carryover of COD to the pulp machine increased compared to the open base case. The other concept, based on semi-countercurrent washing, made it possible to reach an effluent flow of 11.4 metric tons/a.d. metric ton, containing 26 kg COD/a.d. metric ton and fresh water usage of 2.1 metric tons/a.d. metric ton. In this case, the carryover of COD to the pulp machine was comparable with the base case.

Two parameters of importance are the NPEs in wood and pulp and the purity of the sodium hydroxide makeup. In particular, the calcium and barium content in wood and pulp are crucial for the degree of closure that can be attained. The highest risk of calcium oxalate precipitation is around the D_0 stage. The risk can be reduced by decreasing the pH and/or increasing the temperature in the D_0 stage. By using sodium hydroxide produced by the membrane technology, with a low chloride content, it is possible to further increase the recirculation of the alkaline filtrates to the brownstock washer.

This work is based on the assumption that the process is in steady state. In a real mill, this is seldom the case; warm and cold areas exist in the process and there could be variations in the process conditions. With significant changes in the conditions, severe scaling could occur. It is therefore important to keep in mind that the implementation of the outcome of this study in a real mill must be done with care and in a step-wise manner. The indicated positions for precipitations could serve as a guideline for manual inspections during a maintenance stop. **TJ**

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LITERATURE CITED

1. STFI, "Ecocyclic pulp mill. Final report from the KAM program 1996-2002," KAM Report A100, STFI, Stockholm, 2003.
2. Reid, D.W., Johansson, N.G., Petre, K.L., et al., "Evaluation of bleach plant partial closure for an operating North American ECF market kraft pulp mill," *1997 Minimum Effluent Mills Symp.*, TAPPI Press, Atlanta, GA, USA, 1997.
3. Reid, D.W., Hicks, A.G., Clark, F.M., et al., "Evaluation of bleach plant partial closure, part two: a North American ECF kraft mill with oxygen delignification," *TAPPI Pulping Conf.*, TAPPI Press, Atlanta, 1998.
4. Berglin, N., Lovell, A., Delin, L., et al., "The 2010 reference mill for kraft market pulp," *TAPPI PEERS Conf.*, TAPPI Press, Atlanta, 2011.
5. Ulmgren, P. and Rådeström, R., *Nord. Pulp Pap. Res. J.* 14(3): 214(1999).
6. Ulmgren, P. and Rådeström, R., *Nord. Pulp Pap. Res. J.* 14(4): 330(1999).
7. Ulmgren, P. and Rådeström, R., *Nord. Pulp Pap. Res. J.* 16(4): 389(2001).
8. Ulmgren, P. and Rådeström, R., *J. Pulp Pap. Sci.* 27(11): 391(2001).
9. Wadsborn, R., Samuelsson, Å., Rådeström, R., et al., "Metal profiles in the bleach plant: Modelling and mill validation," *Int. Pulp Bleaching Conf.*, SPCI/STFI-Packforsk, Stockholm, 2005.

ABOUT THE AUTHORS

The growing global population and the increasing scarcity of freshwater in the world accentuate the need for the pulp and paper industry to lower its water footprint. Efficient water use is an important factor in achieving more sustainable pulp production. In this study, we wanted to identify options for significantly decreasing (fresh) water usage in an ECF bleach plant, thereby decreasing the volume of effluent emitted to the recipient.

Earlier, we studied a generic pulp mill producing eucalyptus pulp with typical Brazilian conditions. In this study, we were interested in also evaluating the possibilities to reduce the water usage in a mill producing softwood pulp using conditions more "typical" for North America. The most difficult aspect of this work was to design a general simulation model representing a "typical" North American mill.

Our most interesting finding in this study was the importance of using a sodium hydroxide quality with a low content of chlorides. For mills, the method



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used in this study can be applied in a specific mill case in order to evaluate different closure strategies and find ways to further reduce the freshwater use in the bleach plant. Our next step is to verify the simulation results in a real mill situation and to develop solutions for the potential limitations identified to make it possible to reach a lower water usage.

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