

Removal of dissolved and colloidal substances in water from compressive pre-treatment of chips using dissolved air flotation. Pilot trial

Mihaela Tanase Opedal, Per Stenius, Lars Johansson, Jan Hill, and Christer Sandberg

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SUMMARY: In this paper, we report on an investigation of the removal of dissolved and colloidal substances in water from compressive pre-treatment of wood chips (process water from compressive pre-treatment) using a pilot dissolved air flotation (DAF) unit in a paper mill. The flotation efficiency technique was evaluated by measuring turbidity, chemical oxygen demand (COD), and the amounts of extractives, carbohydrates and lignin present in the subnatant before and after flotation. Factors such as pH and temperature of the pressate water from compressive pre-treatment affect the efficiency of DAF and are discussed. The results show that the best removal efficiency (up to 76% removal of extractives) was obtained by using a combination of a high molecular weight, low charge density polymer (C-PAM) with a low molecular weight, high charge density polymer (poly-DADMAC + C-PAM) in the mass ratio 1:1.

ADDRESSES OF THE AUTHORS: **Mihaela Tanase Opedal** (mihaela.tanase.opedal@pfi.no): Norwegian University of Science and Technology, Dept. of Chemical Engineering, NO-7491, Trondheim, Norway, **Per Stenius** (per@stenius.com): Professor emeritus, Centralvägen 18F, 18432 Åkersberga, Sweden, Professor **Lars Johansson** (lars.johansson@pfi.no): Paper and Fibre Research Institute, NO-7491, Trondheim, Norway, **Jan Hill** (jan.hill@qtab.se): P.O. Box 39, SE-28221 Tyninge, Sweden, NSI Focus, Norske Skog ASA, N-1756, Halden, Norway, **Christer Sandberg** (christer.sandberg@holmenpaper.com) Holmen Paper, Development Centre, SE-601 88, Norrköping, Sweden

Corresponding author: Mihaela Tanase Opedal
Present address Paper and Fibre Research Institute, NO-7491, Trondheim, Norway (mihaela.opedal@pfi.no)

In pulp and paper mills, decreasing the fresh water consumption and closing the mill water circulation results in accumulation of dissolved and colloidal substances in the white waters. These substances may cause various problems in the papermaking process, including lower wet strength of the paper web, formation of deposits and corrosion. They also may affect the mechanical and optical properties of the paper, as well as odour and taste in the final product (Allen 1975; Sundberg 1996; Sundberg 2000; Cisneros and Drummond 1995). Deposits are often formed when the colloidal stability is weakened so that the colloidal extractives aggregate. In order to avoid these problems, cationic polymers are added to fibre suspensions with the aim to fixate the colloidal substances to the paper by reduced electrostatic

repulsion (i.e. by neutralizing the particle charge) or by introduction of attractive forces, such as bridging. In both cases, the polymers act as flocculants. If added in excess, they can also act as stabilizers, if their adsorption changes the forces between the surfaces to repulsive, such as steric or electrostatic repulsion due to charge reversal (Stenius 2000).

In order to reduce the environmental impact of pulp and paper production, small water process streams can be treated to remove both dispersed solid material and dissolved substances before they reach toxic levels in the process water or before the water is sent to the effluent plant. Therefore, it becomes necessary to eliminate harmful substances as early as possible in the beginning of the process or at least to decrease their negative effect. Apart from binding them in to the paper web, dissolved and colloidal substances can be removed from the white water and wastewater by sedimentation, filtration, flotation and reverse osmosis.

Tanase et al. (2010) found that up to 40% of extractives are released when using a compressive pre-treatment of wood chips, such as an Impressafiner. Moreover, also other substances contributing to chemical oxygen demand (COD) are squeezed out. On the other hand, in the COD from the Impressafiner there will be very few fibres.

In this study, a flotation technique (i.e. Dissolved Air Flotation, DAF) was used for removal of flocculated extractives from the Impressafiner pressate water.

In DAF particles in the size range from a few μm upwards are removed by attaching them to micro bubbles that are generated when a pressurized solution of air in water is released into the flotation cell. It is well known that flotation of particles smaller than a few μm is inefficient because hydrodynamic effects on particle collisions decrease the probability of attachment of small particles to much larger bubbles (Han 2001). The size of the colloidal extractives is generally less than a few μm . Thus, they must be flocculated before flotation.

Richardson and Grubb (2004) investigated the removal of extractives from thermomechanical process water by DAF. They found that 80-90% of the fibre-bound and colloidal extractives could be removed in this way. DAF has also been beneficially applied for removal of extractives in a eucalyptus kraft mill in order to control pitch deposition (Negro et al. 2005) and for removal of detrimental substances from peroxide-bleached TMP water (Saarimaa et al. 2006).

In an earlier study (Tanase et al. 2011a), we investigated the flocculation of colloidal extractives present in pressate water from Impressafiner with different cationic polymers (poly-DADMAC, C-PAM and combination of the polymers). It was shown that these polymers

efficiently flocculate colloidal extractives present in pressate water from Impressafiner via two different flocculation mechanisms: charge neutralization and bridging flocculation.

Subsequently (Tanase et al. 2011b) we investigated the removal of the flocculated extractives by flotation in a laboratory scale DAF unit. The pressate water samples had been stored in frozen condition before the investigation. It was shown that a combination of the polymers gave the best results, both in the flocculation of colloidal extractives and in the efficiency after DAF. The flocculated extractives could be floated with a removal efficiency of 80%.

This paper reports on an assessment of the potential benefits of DAF in mill scale, using the laboratory results as a background. The removal of flocculated lipophilic extractives from fresh Impressafiner pressate water using a pilot DAF unit in a paper mill was investigated.

Materials and methods

Process water and extractives

The pressate water samples were collected from the equipment used for pre-compression of chips (Andritz 500 D Impressafiner) in the TMP B line at Holmen Paper Braviken mill, Sweden. Details of the process are given by Tanase et al. (2010). In order to simulate a real DAF process conditions, pressate water samples were collected and used directly in the pilot DAF unit at the mill site. The raw material was 100% Norway spruce.

The water used for creation of air bubbles in the DAF tests was pressurized water saturated with air at 6 bar from the deinking plant at the mill. More details are given in *Table 2* and *Table 3*.

Chemicals

Solutions of Poly-(N-N-dimethyldiallyl-3-4-ethylenpyrrolidonium)chloride, Poly-DADMAC, i.e. a polymer with high charge density (*CD*) and low molar mass (M_w) and cationically modified polyacrylamide, poly-(trimethyl(3-methacrylamidopropyl)-ammonium)chloride, C-PAM, a polymer with high M_w and low *CD* (Kemira Oyj, Finland), were used (*Table 1*). The polymers were used as delivered without further purification.

Experimental methods

Polymer addition

Flocculation with single polymer (Poly-DADMAC, C-PAM) and a mixture of the polymers (Poly-DADMAC + C-PAM, 1:1 mass ratio) was studied.

The concentrations of the polymers necessary to reach zero electrophoretic mobility (isoelectric point) were determined in previous laboratory experiments (Tanase et al. 2011b). They were: poly-DADMAC 1 mg/l, C-PAM 50 mg/l and combination of the polymers (Poly-DADMAC + C-PAM, 1:1 mass ratio) 20 mg/l. The concentrations of the polymers used in the pilot DAF trial were chosen to be the concentrations around these isoelectric points.

Prior to experiments, solutions of Poly-DADMAC

Table 1. Properties of the cationic polymers used, Poly-DADMAC and C-PAM. *DS* is the degree of substitution, i.e. the fraction of monomers in the polymer that carries a cationic group and *CD* is the charge density.

Substance	M_w 10 ⁶ g/mol	<i>CD</i> meq/g	<i>DS</i> %
Poly-DADMAC	0.17	6.2	100
C-PAM	7.0	0.3	2.0

(0.3 g/l) and C-PAM (0.8 g/l) were prepared. Appropriate amounts of C-PAM, Poly-DADMAC and the combined polymers were added to pressate water during rapid agitation (1 min), in order to promote the interaction of the flocculants with dispersed organic substances and to facilitate the growth of the flocs. In the case of combination of the polymers (C-PAM + Poly-DADMAC), the Poly-DADMAC was added first with a gap of 10 sec before adding the C-PAM in order to allow the adsorption of Poly-DADMAC on the particle surface.

Dissolved air flotation (DAF) tests were performed in a pilot flotation unit (*Fig 1*) at 70°C and at pH 6.6 -7.1. Process water from Impressafiner was filtered on a plastic wire to remove large particles and mixed with different concentrations of polymers. The DAF cell was filled with 10 L sample.

Air-saturated water (temperature 70°C, pH 7.1) was injected in the middle of the flotation cell in a continuous flow, 2 l/min (the pressure used in our experiments was 6 bar). Flocs formed by the polymers and extractives attached to the bubbles and rose up to the surface. The subnatant was subjected to analysis of turbidity, chemical oxygen demand (COD) and lignin as well as content of carbohydrates and extractives.

Turbidity was measured in Nephelometric Turbidity units (NTU), using a laboratory turbidimeter (Hach Model 2100AN). The turbidity of the subnatant after DAF, was measured as a function of the amount of cationic polymer added to the Impressafiner pressate water (1500 g, 10min).

The Chemical Oxygen Demand, COD, was measured according to the Dr. Lange method (ISO 6060-1989).

The residual **lignin** was determined by extracting the lignans from the process water with methyl tert-butyl ether (MTBE) (Örså and Holmbom 1994) and measuring the absorbance at 280 nm using a UV-Vis spectrophotometer.

The amount of **carbohydrates** was determined using the methods described by Chaplin and Kennedy (1986). 1 ml of the water to be analysed was mixed with 1 ml

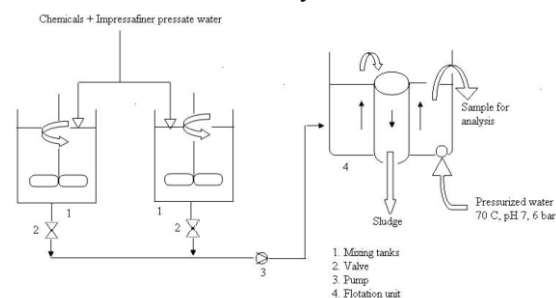


Fig 1. Scheme of the pilot dissolved air flotation unit

phenol solution (5 g/100 ml) and 5 ml concentrated sulphuric acid (96%). Thereafter, it was allowed to cool down for 10 minutes, mixed well and left for cooling for 30 minutes. The total amount of carbohydrates (see Table 3) was determined by measuring the absorbance at 490 nm, using plastic cuvettes.

The amount and composition of extractives was analyzed by extraction of the process water with methyl tert-butyl ether (MTBE), using the method described by Örså and Holmbom (1994). The amounts are given in Table 3.

The total amount of extractives in the chips that enter the Impressafiner was calculated by measuring the water flows around the Impressafiner. For more details see Tanase et al. 2010.

The resin acids, triglycerides and fatty acids components of the extractives were measured as total, colloidal and dissolved form. The dissolved and colloidal fraction was isolated by centrifuging the total sample of 500 g for 30 min. The colloidal fraction was then removed by ultrafiltration using an Amicon cell with a 0.1 µm filter. Based on this procedure the material in the pressate water could thus be classified as fibre bound (removed by centrifugation, i.e. total-dissolved-colloidal), colloidal (removed by centrifugation and filtration, i.e. total-dissolved) and dissolved (remaining after filtration through 0.1 µm filter)

Results

Composition of pressate and pressurized water

The characteristics of the Impressafiner pressate water and pressurized water used in the pilot DAF trial is shown in Table 2. The classification and composition of the material in the pressate water are given in Table 3.

It is noteworthy that the concentrations of fatty acids, esters and resin acids were considerably reduced already by centrifugation at speeds that will not remove colloidal material. Obviously part of these compounds were either dispersed as relatively large particles or, as is more likely, were bound to fibre fragments that were removed in the centrifugation. In the discussion below, this fraction will be denoted as fibre bound. Within experimental accuracy, no lignans or sterols were removed by centrifugation or filtration. The triglycerides were completely insoluble in water and were released from the chips either bound to fibre fragments or as colloidal particles.

The composition of pressurized water is given in Table 3. The water contained some extractives, carbohydrates and lignans, but the concentrations were much smaller than those in the water from the Impressafiner.

Dissolved air flotation

Figs 2-6 describe flotation efficiency as a function of the amount of polymer added to the pressate water. In the graphs and in the calculations, the amount of dissolved and colloidal substances added with the pressurized water was taken into account.

Fig 2a and Fig 2b summarizes the flotation efficiency in terms of residual turbidity of the subnatant after flotation. The turbidity decreased with increasing polymer dosage,

Table 2. Characterization of the Impressafiner pressate water and pressurized water (initial).

	Impressafiner pressate water	Pressurized water
pH	6.6	7.1
Residual turbidity, NTU	711	20
COD, mg/l	6050	2383
Lignin, mg/l	582	352

indicating that the air bubbles after flocculation of the particles lifted the colloidal unstable particles and flocs to the surface.

Using Poly-DADMAC as the flocculation agent DAF reduced the turbidity of pressate water by only 7% at a polymer concentration of 20 mg/l. On the other hand, using C-PAM as flocculation agent the DAF reduced the turbidity by 95% at a polymer concentration 75 mg/l. The use of C-PAM in combination with Poly-DADMAC (1:1 mass ratio) gave the best reduction in turbidity (97%) at the polymer concentration 50 mg/l.

Fig 3a and Fig 3b summarizes the flotation efficiency in terms of concentration of extractives in the subnatant after flotation. When Poly-DADMAC was used alone as flocculation agent, the total amount of lipophilic extractives was reduced by about 45% at a polymer concentration of 2.5 mg/l. The concentration was not further reduced by adding up to 20 mg/l Poly-DADMAC.

When C-PAM was used as flocculation agent for Impressafiner pressate water the total amount of lipophilic extractives was reduced by more than 70% at already at a polymer concentration of 10 mg/l. Adding more polymer slightly increased reduction to reach 75% at a polymer concentration of 75 mg/l.

C-PAM in combination with Poly-DADMAC (1:1 mass ratio) behaved roughly in the same way as C-PAM alone and gave the best reduction in total amount of lipophilic extractives for Impressafiner pressate water (76%) at polymer concentration 50 mg/l.

Table 3. Concentrations of lipophilic extractives, lignans and carbohydrates in process water from Impressafiner and in the pressurized water used in flotation.

	Impressafiner pressate water				Press- urized water mg/l
	Before centrif. mg/l	After centrif. mg/l	After ultrafiltr. mg/l	*As colloid mg/l	
Fatty acids	56	35	17	18	16
Resin acids	204	93	18	75	19
Lignans	143	149	153	-	78
Sterols	20	17	18	-	8
Steryl esters	44	25	11	14	8
Triglycer.	48	21	0	21	0
Carbohydr.	1434				554

* As colloidal is the difference between after centrifugation and after ultrafiltration.

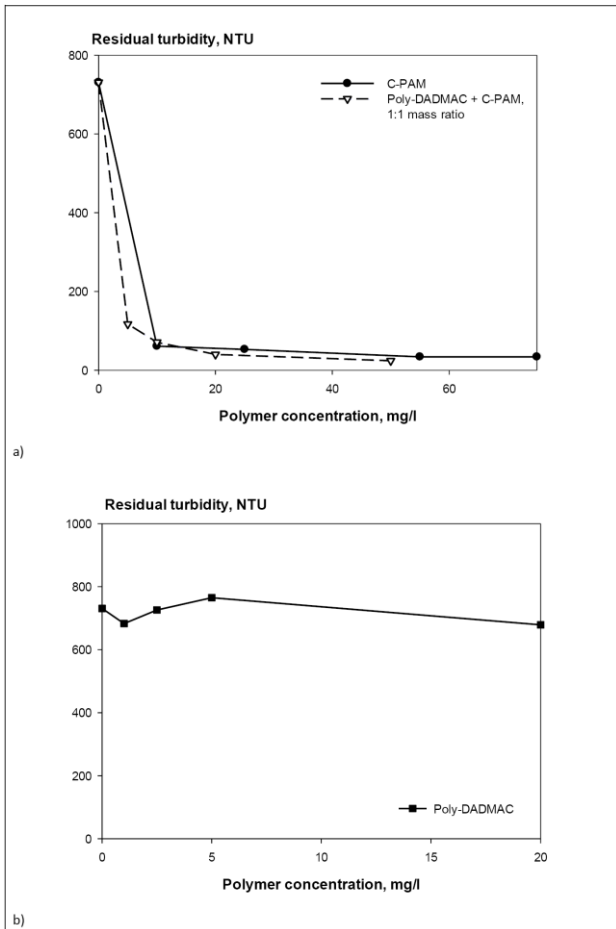


Fig 2. Residual turbidity of Impressafiner pressate water after DAF: a) C-PAM and combination of the polymers; b) Poly-DADMAC.

Figs 4a and 4b summarize the flotation efficiency in terms of the concentration of carbohydrates in the subnatant after DAF. The lowest reduction of carbohydrates was obtained when using Poly-DADMAC as flocculation agent. The amount of carbohydrates was reduced by 55% already at a polymer concentration of 2.5 mg/l, but then remained the same up to the maximum concentration of Poly-DADMAC added (20 mg/l). When C-PAM was used as flocculation agent the amount of carbohydrates was reduced by 66% when 10 mg/l was added, the concentration then remained constant up to a polymer concentration of 75 mg/l.

The combination of the polymers (C-PAM + Poly-DADMAC) gave about the same reduction as C-PAM alone. The amount of carbohydrates was reduced by 67%, at a polymer concentration 50 mg/l. The amount of lignin after flotation is shown in Figs 5a and 5b. C-PAM and the combination of the polymers reduced the amount of lignin by about 66% at the lowest additions of polymer used. Additional C-PAM did not further reduce the amount, but with the combination of polymers the reduction increased slowly to reach 71% at the polymer concentration 50 mg/l. Poly-DADMAC reduced the amount of lignin by 60% at polymer concentration 2.5 mg/l with no further reduction when the polymer concentration was increased to 20 mg/l.

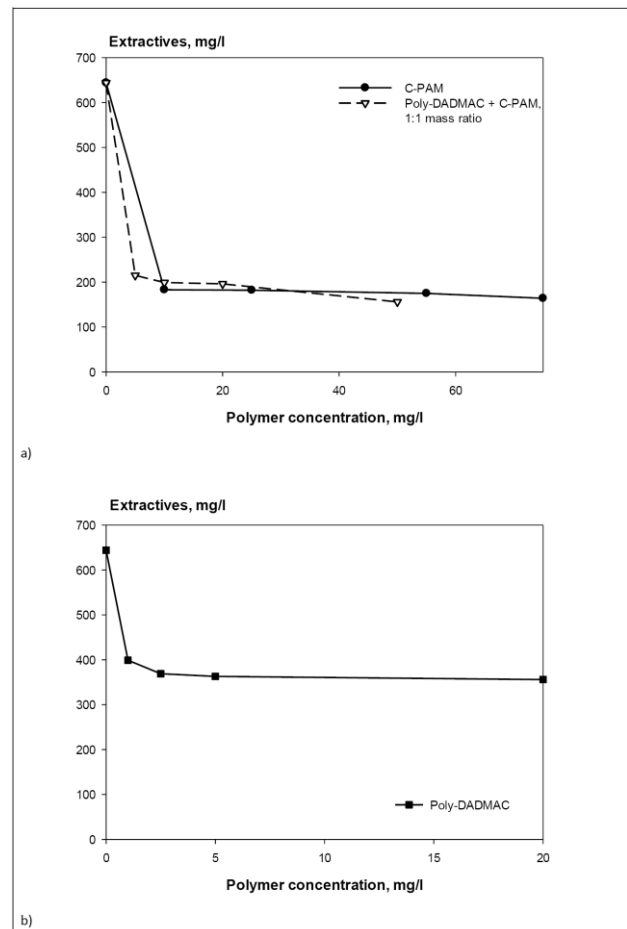


Fig 3. The amount of lipophilic extractives in Impressafiner pressate water after DAF: a) C-PAM and combination of the polymers; b) Poly-DADMAC.

Figs 6a and 6b summarize the flotation efficiency in terms of chemical oxygen demand (COD). Adding C-PAM alone resulted in a reduction of COD by about 71% at the lowest polymer dosage used. Additional C-PAM did not further reduce the COD level. The combination of polymers was slightly less efficient at low polymer concentration, but reduced the COD by the same amount as C-PAM alone at 50 mg/l. When Poly-DADMAC was used alone as flocculation agent, the COD was reduced by approx. 60% at the lowest polymer concentration added. There was no further reduction up to the highest polymer concentration 20 mg/l. The contribution of extractives, carbohydrates, lignin and lignans to the total COD levels were calculated using the conversion factors (Lenes et al. 2001). We have found that approx. 40% of the COD was given by carbohydrates, 30% of COD was given by extractives and 30% of COD was given by lignin.

Discussion

Comparison of pilot and laboratory trials

The results presented in Figs 2-6 show that substantial amounts of dissolved and colloidal substances were removed from the Impressafiner water by flocculation with cationic polymers followed by DAF. The reductions

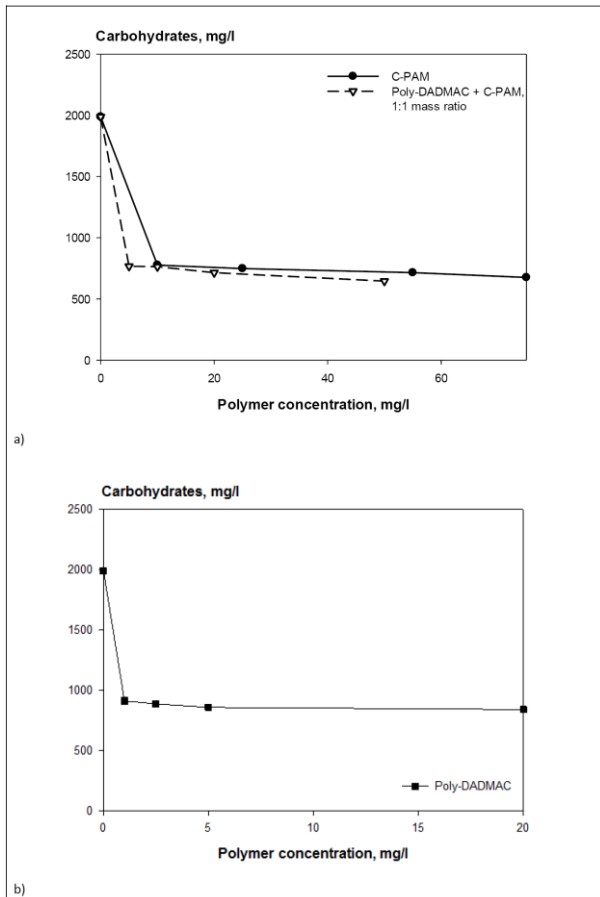


Fig 4. The amount of carbohydrates in Impressafiner pressate water after DAF: a) C-PAM and combination of the polymers; b) Poly-DADMAC.

of dissolved and colloidal substances after DAF are qualitatively in agreement with those obtained previously in laboratory scale experiments with Impressafiner water taken earlier from the same mill. In both cases it was evident that there was no direct correlation between the amounts of polymer required to achieve efficient flotation and the isoelectric point of the colloidal particles. Quantitatively there are differences between the experiments that yield some insight into the flocculation mechanism. To facilitate further discussion relative changes in the properties of laboratory and pilot trial waters after addition of 20 mg/l polymer are compared in *Table 4*

This concentration was chosen because it was the highest concentration of pure Poly-DADMAC used in the pilot trial and there was little change in properties when adding higher concentrations of the other polymers.

The first important difference is that turbidity was only marginally decreased by addition of Poly-DADMAC alone in the pilot experiments. This could also be visually observed: after flotation with Poly-DADMAC the water was still turbid without any visible flocs while addition of C-PAM or the combination yielded large, visible flocs. In the laboratory trial the turbidity decreased continuously on further addition above 20 mg/l to reach 80% at 100 mg/l Poly-DADMAC. Nevertheless, the chemical analyses showed that extractives, carbohydrates and lignin were removed by the pilot DAF after addition of Poly-DADMAC.

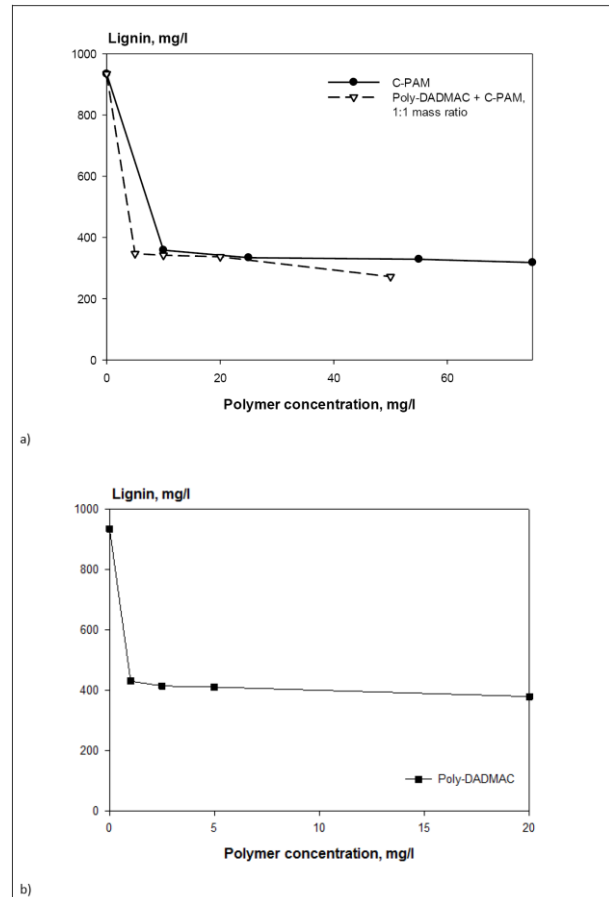


Fig 5. The amount of lignin in Impressafiner pressate water after DAF: a) C-PAM and combination of the polymers; b) Poly-DADMAC.

The most likely explanation is that Poly-DADMAC, which is a relatively low molecular mass and high charge density polymer, reacted preferentially with dissolved carbohydrates and to some extent with extractives, forming small, compact flocs, while the polymer did not flocculate the small fibre fragments that, hence, remain in the water after flotation and contribute strongly to turbidity.

The water used in the laboratory experiments had been frozen before the experiments. It is therefore very likely that the amount (and state of aggregation) of fines in the water used in laboratory trial might have been different from the amount of fines in the water taken directly from the mill. Such differences have been reported earlier in the literature (Willför et al. 2006).

Solubility of extractives

Factors such as pH and temperature of the Impressafiner pressate water may also be part of the explanation of differences in the efficiency of the DAF.

Laboratory DAF results showed that 40-45% of the extractives in Impressafiner pressate water were fibre bound, 35-40% were in colloidal form and 13-15% were dissolved. The Impressafiner pressate water used in the pilot DAF trial contained 45-50% of fibre bound extractives, 30-35% extractives in colloidal form and 17-20% dissolved extractives

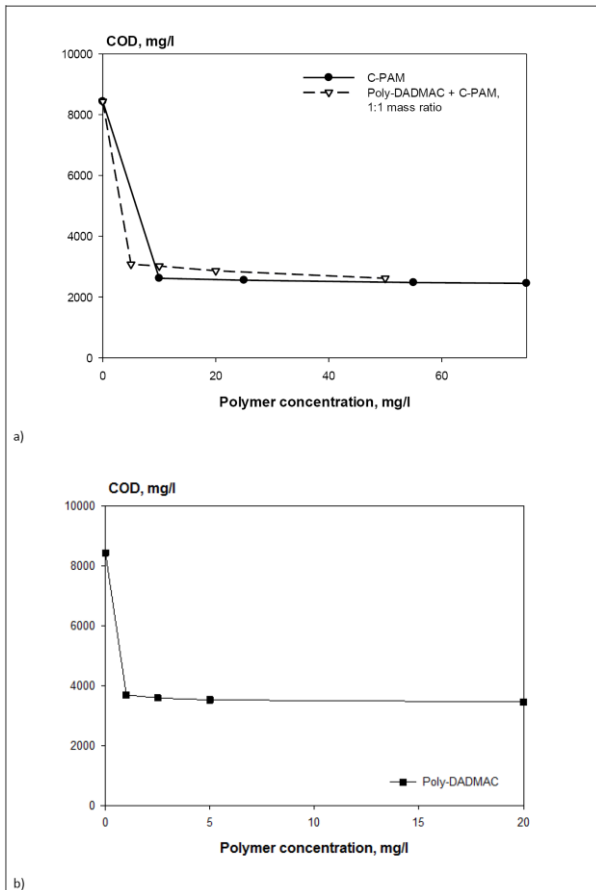


Fig 6. COD of Impressafiner pressate water after DAF: a) C-PAM and combination of the polymers; b) Poly-DADMAC.

In the pilot DAF trial the pH of the Impressafiner pressate water was 6.6 which was higher than in the laboratory tests (pH 5.5). Moreover, the pH of the air-pressurized water used in the pilot trial was 7.1. It was shown by Sundberg et al. (2009) that the pH of the process water affects not only the degree of dissociation of the carboxyl group but also determines the phase distribution of fatty and resin acids between the water phase and the colloidal phase, see Fig 7.

In accordance with the results in Fig 7, our pilot DAF results show that the concentration of dissolved extractives in the Impressafiner pressate water was higher than in the laboratory experiments (17-20%) compared with laboratory results (13-15% dissolved extractives). It seems that the phase distribution of extractives affect the efficiency of DAF. In agreement with our results, Richardson and Grubb (2004) have shown that the phase distribution of extractives between fibre bound, colloidal and dissolved affect the efficiency of DAF and that the fibre bound and colloidal extractives can be removed with a removal efficiency of 80-90%. However, the dissolved extractives were removed with a very low efficiency (30%). The temperature of the Impressafiner pressate water may also affect the efficiency of DAF. Experiments in the pilot trial were carried out at 70°C while laboratory experiments were carried out at 25°C. Negro et al (2005) noted the solubility of air in the pressurized water will be lower at higher temperature.

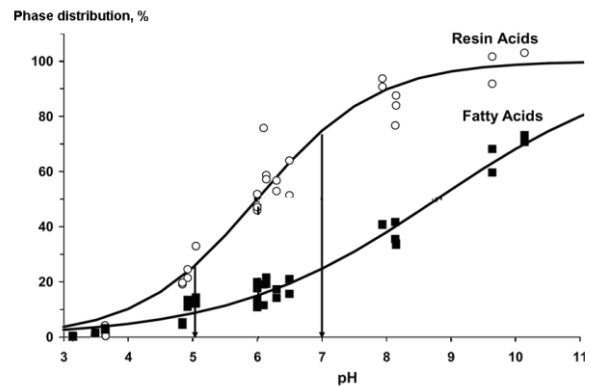


Fig 7. The phase distribution of fatty and resin acids (adapted from Sundberg et al. 2009).

Table 4. Relative reductions in properties of pressate water from Impressafiner (%), after addition of 20 mg/l of flocculating polymer. Data for laboratory scale experiments from Tanase et al. (2011b).

	C-PAM		C-PAM + Poly-DADMAC, mass ratio 1:1		Poly-DADMAC	
	Lab	Pilot	Lab	Pilot	Lab	Pilot
Turbidity	66	93	82	94	26	7
Extractives	53	65	61	62	34	45
Carbohydrates	31	48	42	50	29	58
Lignin	16	43	22	42	44	59
COD	36	58	51	53	37	59

This may also contribute to the lower removal efficiency at the higher temperature. For example, at 6 bar the amount of air in saturated water at 20°C is 36% higher than the amount at 40°C (Ross et al. 2000). On the other hand, the higher temperature of the process water implies that the kinetics of the flocculation (collision rate) is faster.

The reduction in the COD involves the removal of negatively charged particles present in the TMP process water. Thus, the removal of wood extractives significantly contributes to COD reduction.

It is known from the literature that washing mechanical pulp (i.e disc filter, screw presses, etc) is a good way to reduce the COD and extractives content in the pulp, but in this case fibre recovery equipment is required (Käyhkö 2002; Braeuer et al. 2008). Fibre recovery implies that parts of extractives are recirculated back into the process.

Flocculation mechanisms

In our previous study (Tanase et al. 2011b) the measurements of particle size distribution of the pressate water from Impressafiner after DAF confirmed that the large flocs (100-1000µm) were efficiently removed by DAF. The higher removal efficiency of large aggregates could be explained by the collision efficiency. Han (2001) showed that the collision efficiency, which is determined by shear forces (mixing) and on the rate at which particles diffuse toward each other, increases as the particle size increases above 1 µm and that the

maximum efficiency is obtained when the particles and bubbles are of similar sizes.

Under turbulent mixing the flocs formed by charge neutralization may actually be not formed at all, because attraction is too short range to overcome repulsive hydrodynamic interactions (Stenius 2000). This statement can be a possible explanation on why the single polymer that did not form extensive loops protruding into the solution (Poly-DADMAC) showed the lowest removal efficiency (Figs. 2 and 3).

On the other hand the C-PAM-induced bridging flocculation mechanism yields large flocs and removal efficiency is higher. This interpretation is supported by the different flocculation mechanisms observed in the experiments described in our previous papers (Tanase et al. 2011a, b).

The combination of the polymers (Poly-DADMAC+C-PAM) showed the highest removal efficiency (the polymer with the highest ability to remove dissolved and colloidal substances) in terms of total amount of lipophilic extractives in the subnatant after DAF. The difference between this system and C-PAM alone in terms of turbidity decrease was not significant, but the data in Table 4 show that the reduction of extractives, carbohydrates and lignin was actually larger when the combination of the polymers was used.

Notes on application

A theoretical mass balance can be calculated knowing the consistency of the pulp passing through a screw press, which is generally assumed to be 5-6%. In the press the pulp is dewatered to approx. 28-30% consistency. The filtrate from the screw press, having a consistency of $\approx 0.6\%$, typically contains approx. 4000-6000 mg/l COD. Thus, for a TMP mill with a production of 700 t/d, it was found that screw press squeezes out high volume of water: the flow of the filtrate from screw press will be approx. 110 l/s and the amount of filtrate will be about 9400 t/d.

On the other hand, with compressive pre-treatment of the chips, using an Impressafiner, it is possible to remove extractives from the wood chips before refining, thus reducing the amount of extractives that enter the pulping and papermaking process. Thus the removal of dispersed extractives can be done from water containing very few fibres. For a TMP mill using as raw material Norway spruce, with a production of 700 t/d, it was found that the water flow from combined Impressafiner+Plug screw is approx. 16 l/s, i.e. the amount of water will be about 1380 t/d. The water contained approx. 6500 mg/l COD. This water was found to contain a substantial amount of extractives (about 15% from the total amount of extractives in the chips). These were mainly resin acids which thus could be removed from the chips at an early stage into a small volume of water, while fatty acids remained in the chips (Tanase et al. 2010). Resin acids are generally regarded as the main acute toxicity contributors in TMP effluents (Magnus et al. 2000). Extractives removal efficiency may be further improved by adding chemicals between Impressafiner and Plug Screw.

Further, Plug Screw can squeeze out higher volume of water by increasing the compression ratio.

When using either a screw press or an Impressafiner, the COD and extractives are transferred from the chips/pulp into the process water. Both filtrates from screw press and pressate water from Impressafiner can be sent to a DAF unit, in order to reduce the amount of extractives and COD from the process water, before the water is sent to the effluent treatment or reused internally in the mill. However, the difference is that a screw press generates high volume of water which implies lower efficiency in DAF and higher amounts of COD and resin acids that are sent to the effluent treatment. Reducing COD with one tonne in an effluent plant requires about 1 MWh of energy. Therefore, an effective DAF can reduce the energy needed in the effluent plant. Moreover, large volumes of the process water imply large investments cost for DAF unit and for the flocculation chemicals.

Having a concentrated water stream, such as Impressafiner pressate water, the COD and the amount of extractives are reduced in the beginning of the process, before refining. As a consequence, treatment of Impressafiner pressate water can be done by using small amounts of polymer and smaller DAF unit. Moreover, by reducing the amount of extractives from chips into the water phase and for using DAF unit for treatment of concentrated water stream, the energy consumption required for running a DAF unit is reduced seven times compared to using a DAF unit for treatment of water from a screw press. Thus the total cost is reduced and DAF efficiency is improved.

Conclusions

The pilot trial confirms that extractives and carbohydrates released into water during compressive pre-treatment of wood chips in fibre bound, dissolved or colloidal form can be efficiently removed by flocculation and DAF. This is verified by decrease of COD values, turbidity, amount of extractives, carbohydrates and lignans. Optimization of the process is necessary for high efficiency of DAF.

The removal efficiency depends highly on the type of flocculating polymer used. Moreover, the optimization of coagulation and flocculation is necessary for optimum performance of flotation system.

The best removal efficiency is obtained with a combination of the polymers (Poly-DADMAC + C-PAM, mass ratio 1:1). Using a low molecular mass and high charge polymer (Poly-DADMAC) alone also removes dissolved and colloidal substances, but is less efficient in reducing turbidity.

Factors such as pH and temperature of the pressate water will affect the phase distribution of wood extractives (colloidal, dissolved or attached to fines and fibres) and the efficiency of DAF.

In summary, using DAF for separate treatment of water from the Impressafiner could play an important role in the treatment of process water streams, since it efficiently removes extractives from process water with relatively high concentration of extractives, and thus reduces the risk of a build up of these in the TMP process water loops.

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