Variation of white water composition in a TMP and DIP newsprint paper machine

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ABSTRACT

Analysis of dissolved and suspended solids components showed the variation of white water composition with location on a paper machine. Samples came from points on the forming and press sections at a newsprint mill using thermomechanical pulp and a mixture of deinked pulp containing old newsprint and old magazines. Total suspended solids, total dissolved solids, and ash content data provide a qualitative picture of the removal of white water components from the paper sheet through the wet end of a paper machine.

Application:

Data for total suspended solids, total dissolved solids, and ash content show the effectiveness of the removal of white water components.

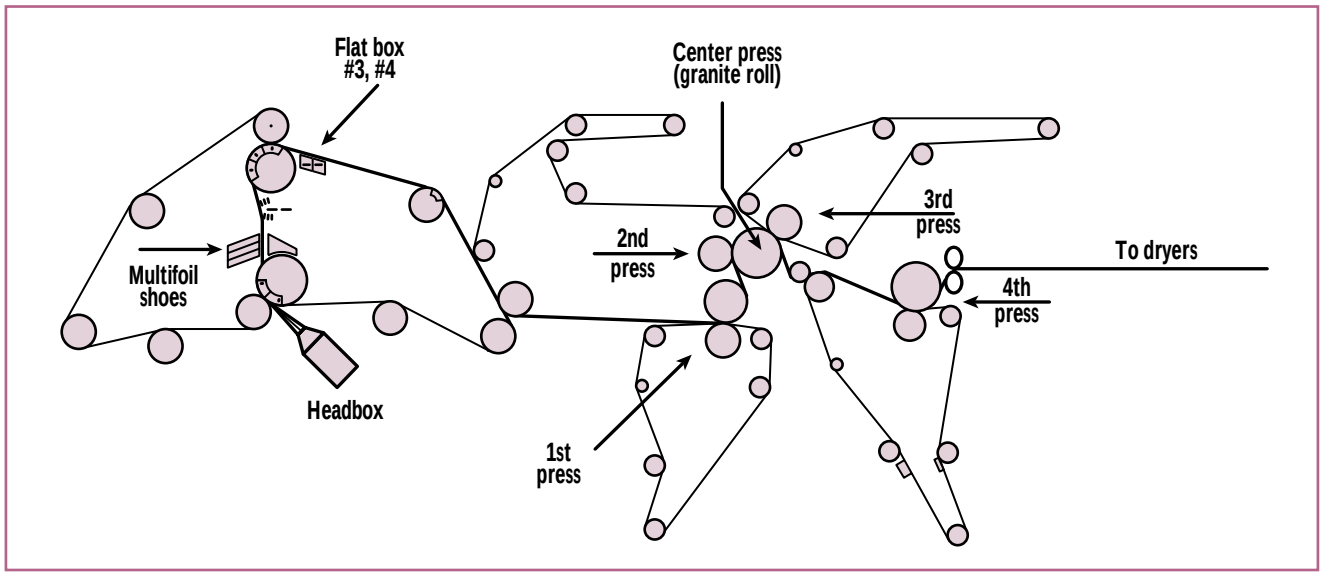
MANAGEMENT AND CONTROL of white water composition are becoming increasingly important as trends in newsprint manufacture lead toward greater closure of white water systems. Objectives for greater closure of the white water system in papermaking include minimization of fresh water use, effluent loading, energy loss, and fiber and fines loss *(1)*. New problems arising from the interactions of white water components derived from thermomechanical pulp (TMP) and recycled pulp components add to the generic problems from system closure, use of polymeric retention aids, and the demands of high-speed paper making.

Today's fast paper machines have high shear and turbulence. These conditions may increase the likelihood of shear-induced deposition and breaks but will reduce floc size and retention *(2, 3)*. Fast paper machines also require tight control of process variables such as pH, temperature, and composition of the white water. Runnability problems that may relate to deposition and accumulation of dissolved substances in the white water include press roll deposition, doctoring problems, felt plugging, sheet "stealing," and drainage problems.

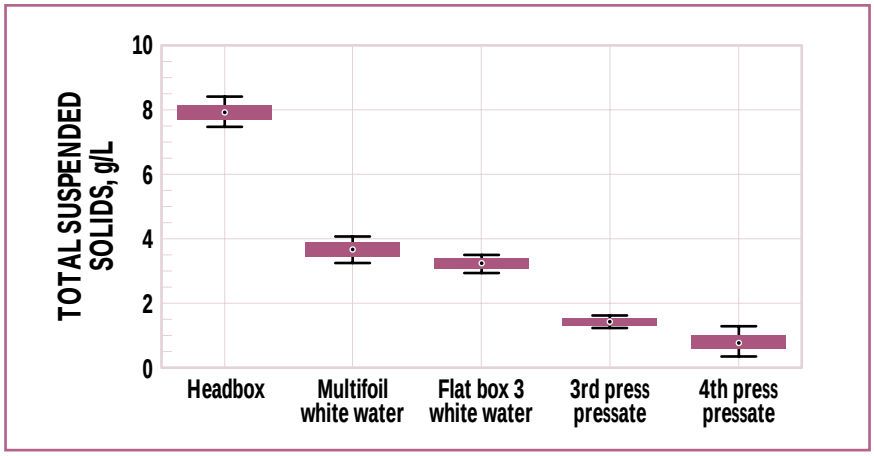
On a high-speed paper machine, improving the retention and drainage with polymers or inorganic additives is an important objective of wet-end chemistry control. Unfortunately, the accumulation of colloidal and dissolved substances within the white water system may reduce runnability, retention, drainage, and the efficiency of retention aids *(4–8)*. The extent to which white water components will accumulate depends on the inputs and outputs to the white water recirculating system. The paper sheet and sewering or countercurrent flow through the mill are the principle outputs *(9)*. The solubility of deposit-forming substances may also limit some components. The loading of the white water system and the corresponding changes in the retention, drainage, and deposition may lead to increased machine breaks, lower paper quality due to decreased paper strength, felt picking, and doctoring problems leading to slug holes. The normally high headbox ash or fines exemplify the accumulation of components due to low retention.

White water in the newsprint paper machine and at different points in the mill contains varying amounts of fiber, fines, and other dissolved and colloidal materials *(9, 10)*. The dissolved and colloidal components consist of inorganic electrolytes, hemicellulose, lipophilic extractives, lignans and lignin derivatives, and process additives *(10, 11)*. Increased temperature, processing time, and pH and decreased ionic strength will increase the dispersion of wood-derived components from TMP during the papermaking process *(12, 13)*. The rapid dispersion of extractives occurs primarily at the first refining stage *(9, 14)*.

One aim of wet-end retention programs is the control of colloidal pitch and stickies. Pitch normally includes lipophilic extractives such as sterols, triglycerides, resin, and fatty acids *(11, 15)*. The term stickies refers to pitch and contaminants from secondary fiber such as hot melts, contact adhesives, sizing agents, ink binders, and coating binders *(16, 17)*. These sticky substances may lead to deposits and reduced paper quality and runnability. Anionic trash is another diffuse term that includes anionic extractives such as resin, fatty acids, hemicellulose, and lignin components. These anionic components increase the cationic demand of the system and thereby reduce the effectiveness of cationic polymers *(6, 18)*. Lignin-derived components *(8, 9, 19)* and hemicellulose components may react with pulp or with cationic polymers *(20, 21)* and reduce the effectiveness of retention aids in retaining colloidal pitch, fines, and clay *(22, 23)*. These anionic species may contribute to a high cationic charge demand or zeta potential for



1. Schematic of the Avenor No. 5 Valmet twin-wire paper machine showing sampling points in the forming section (headbox, multifoil shoes, flat boxes) and the press section (presses 1–4)



2. Variation of suspended solids along the paper machine showing values as an average of five different runs in which the amount of recycled pulp varied over the range 15–35%

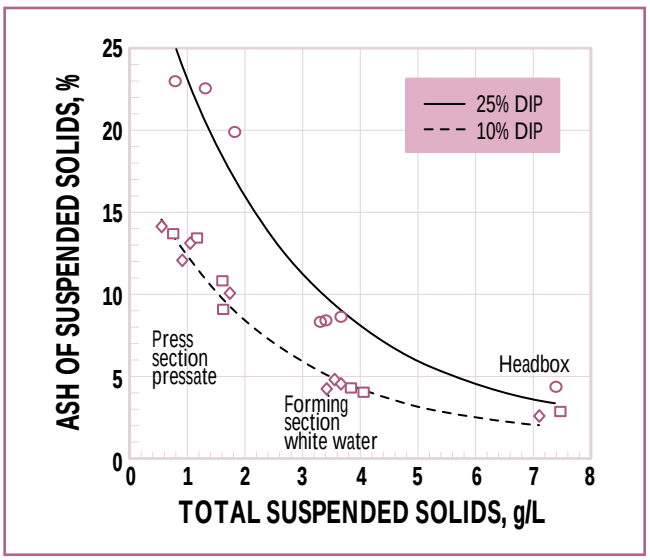
the system that will decrease the retention of anionic components and lead to accumulation of these substances in the white water system *(4)*.

More generalized effects due to electrolyte screening that will reduce electrostatic interactions occurring between particles balance specific ion effects due to competition and binding of electroytes. Derjaguin, Landau, Verwey and Overbeek (DLVO) theory describes the decrease in the electrostatic interactions with increasing salt concentrations leading to a deposition or coagulation between two similarly charged particles at a critical salt concentration *(24, 25)*. Wood pulp has a cation exchange capacity with cation affinities that vary as $Al^{+3} > H^{+} > Ba^{+2} > Ma^{+2} = Ca^{+2} > K^{+} > Na^{+}$. This will vary with the source and the extent of oxidative or hydrolytic formation of carboxyl groups *(26–28)*.

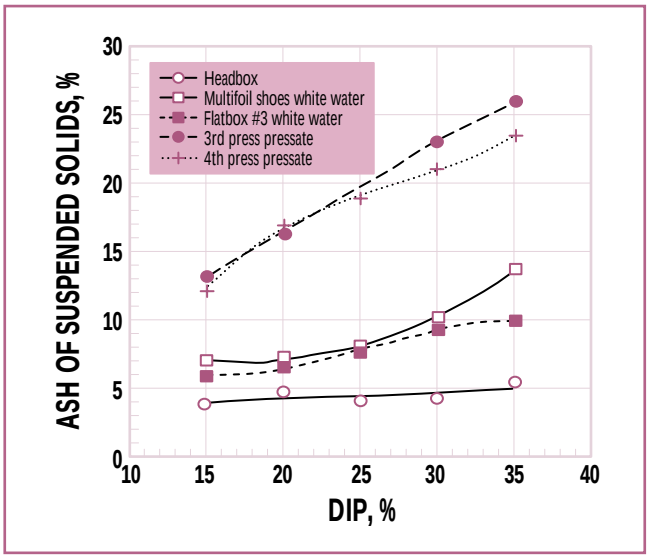
Alexander and Dobbins *(29)* have termed the ions that bind to pulp and undergo removal by the paper sheet as "substantive ions". These include ions of Al, Fe, and Si but do not include nonsubstantive ions of Na, Ca, Mg, and K. Experiments have shown that cationic polymer will displace inorganic cations from pulp as the system nears the isoelectric point *(27)*. Calcium and aluminum ions also change the critical colloid concentration and produce sticky resin and fatty acid soaps. This normally does not occur at pH values below approximately 6 *(30)*.

The objective of this work was to characterize the variation of white water composition from No. 5 paper machine in the Avenor, Thunder Bay, ON, operation for the stock preparation and paper machine zone. It provides basic information on the relative retention processes for fiber, fines, extractives, lignin-like materials, anionic detrimental substances, and metal ions.

In our discussion and analysis, we will assume a uniform concentration of dissolved and colloidal components in the white water at the headbox. Changes in the relative concentration of the different components as the paper sheet forms may be loosely interpreted in terms of selective retention and removal processes. From these results, we may contemplate the role of the physical and chemical properties of



3. The percentage of ash of the suspended solids for different zones in the paper machine for two trials with varying DIP and TMP



4. The percentage of ash at different points in the paper machine for varying amounts of DIP

white water in fouling and deposition processes in the forming and press sections of the paper machine.

EXPERIMENTAL METHODS

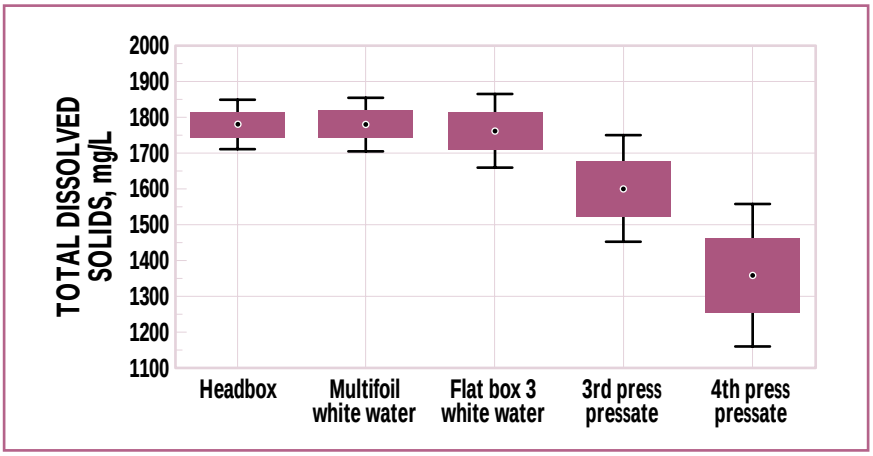
Figure 1 shows the wet end of the paper machine (Valmet twin-wire type) and sampling zones. Five minutes before the white water samples were taken, the shower water was turned off. This was not possible for data sets at 10% deinked pulp (DIP) and the first data set at 25% DIP. These were corrected by adjusting for dilution using measured press pressate and shower flow. The designed production capacity for this paper machine is 850 tons/day (running 650–700 tons/day) with machine speed 1400 m/min (running 1250–1400 m/min). The feed stock to the machine is a mixture of TMP (60–85%), DIP (10–35%), and kraft pulp (5%). The paper machine is run with a headbox pH of approximately 5.1 and a temperature of approximately 50°C. Polymin SK polymer from BASF was the retention aid with inputs of 1.8 kg/ton before the primary pressure screen. This retention aid is a modified cationic polyethylenimine with a charge equivalence of 8 meq/g and a wide molar mass distribution centered at 1–2 million Daltons. Polymin 971 was added to the TMP and DIP pulp at a rate of 1 kg/ton as a fixative. The paper product is newsprint with a basis weight of 48 g/m^2 with 8% moisture.

Location	Ethanol extractives, %	Fines, %	Ash, %	Fiber, %
Headbox	2	60	6	26
Multifoil white water	4.9	90	8	ND
Flat box white water	3.4	85	12	ND
Press 1 pressate	15.3	79	18	ND
Press 4 pressate	10.7	73	22	ND

ND = not determined

1. Typical solids analysis at 10% DIP from the retention monitor and extraction

TAPPI Test Methods *(31)* were used for physical and chemical analysis of white water. The tests on total suspended solids, total dissolved solids (TDS), turbidity, particle charge demand, and ash were conducted in the Avenor (Thunder Bay operation) newsmill laboratory. The UV-visible absorbance of the filtered samples was measured on a Cary 5 UV-visible spectrophotometer after 1:5 v/v dilution with distilled, deionized water. Gravimetric analysis of resin and fatty acids components of white water in the water phase were conducted following established extraction schemes using t-butyl-methyl ether liquid-to-liquid extraction at pH 3.5 *(11, 32)*. The suspended solids were freeze-dried and then subjected to ethanol extraction for 17 h in a Soxhlet apparatus to remove the wood resin, fatty acids, and other extractives absorbed on the fines and clay particles and retained in the suspended solids phase. The fine fraction content in the suspended solids of white water was evaluated by measuring with a BTG RET-5300 retention monitoring unit. Metal analysis of dissolved and suspended solids were carried out with a Jarell-Ash ICAP-9000 inductively coupled plasma (ICP) spectroscopy. Before the ICP analysis, the samples were subjected to acid digestion using a 1:100 ratio of concentrated nitric acid to sample.



5. Variation of dissolved solids along the paper machine showing values as an average of five different runs in which the amount of recycled pulp varied over the range 15–35%

RESULTS AND DISCUSSION

Suspended solids

The main components of white water fall into classes of suspended solids and dissolved solids. Suspended solids consist of fibers, fines, inorganic particles such as coating clay or clay fillers, wood extractives, polymers, and other organics adsorbed on the fines and inorganic particle surfaces. **Figure 2** shows a box-whisker graph indicating the variation of the total suspended solids along the paper machine for five samples with the fraction of recycled pulp in the furnish between 15% and 35%. The box-whisker plot shows the mean at the center, ± σ as a box, and ±1.96 σ as the whiskers.

Suspended solids in the white water at different points on the paper machine were remarkably consistent at different sampling times with no or weak correlation ($|R| < \pm 0.72$) between the amount of recycled furnish and the suspended solids concentrations at each sampling point. As expected, the suspended substances in the white water decreased from the headbox through flat box to the fourth press. The sampling zones can be grouped according to the forming and pressing sections representing the different suspended solids level.

A filtration retention mechanism can explain the lower suspended solids as the web consistency increases. During the wet web formation, the paper machine acts as a filtration and dewatering device. In the forming section, the mat is coarse. Fewer fines are entrapped and more fines pass through the medium with white water. As the sheet web consolidates and more of the mat network builds up, increasing amounts of fines are entrapped in the interstices of the fibrous mat.

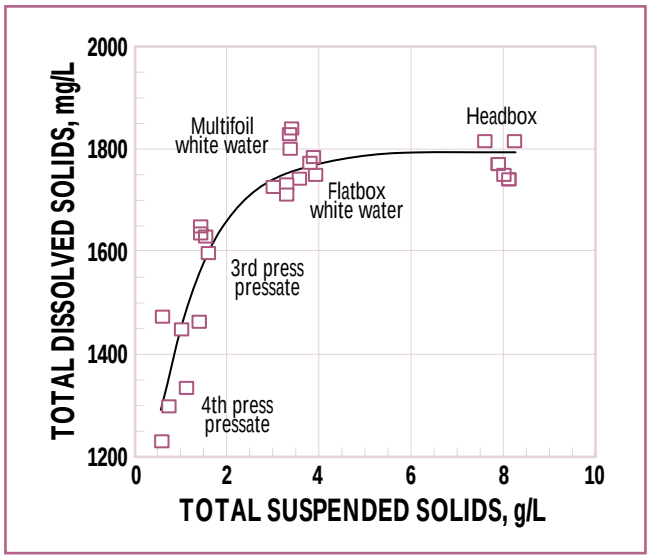
The lower total suspended solids in the press section white water are also the result of press felt functioning as a filter to retain suspended solids. The retention of different size organic and inorganic particles also depends on the effectiveness of the polymer retention aids.

The ash content of the suspended solids in the white water represents the relative amount of inorganic materials that include clay, talc, and insoluble calcium salts depending on the furnish preparation. **Figure 3** gives the ash percentage vs. total suspended solids in the white water. **Table I** gives a characterization of white water for fiber, fines, ash, and extractives determined by Soxhlet extraction of the suspended solids.

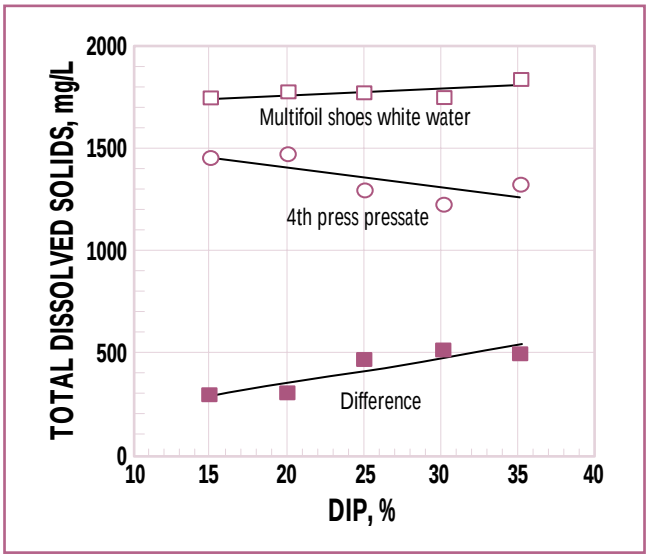
The relative ash content in the press white water is higher than that in the forming section and the headbox, although the total amount of ash decreases approximately 50% between the headbox and the press section. The higher relative amounts of ash in the press section white water could simply be due to the lower fiber and fines content in the press white water. Figure 3 also shows that when the DIP ratio increases from 10% to 25%, the ash percentage in every sampling point increases approximately twice. The suspended solids fraction of ash or clay increases as the sheet forms and the fraction of extractives present also increases. What remains in the press section is a heterogeneous mix of clay and extractives that commonly forms fine flocs in the white water.

Increasing the DIP ratio or machine speed has often led to increased breaks on the paper machine at the press granite roll at this mill. IR, ICP metal analysis, and SEM/energy dispensive x-ray analysis (EDXRA) micro-elemental analysis (not shown) reveal that clay particles are the major components of the inorganic ingredients in deposits and the white water. This result suggests that the high ash levels in the press section white water may relate to runnability problems occurring by plugging of the fourth press doctors, high hole counts of the paper sheet, and unscheduled doctor changes.

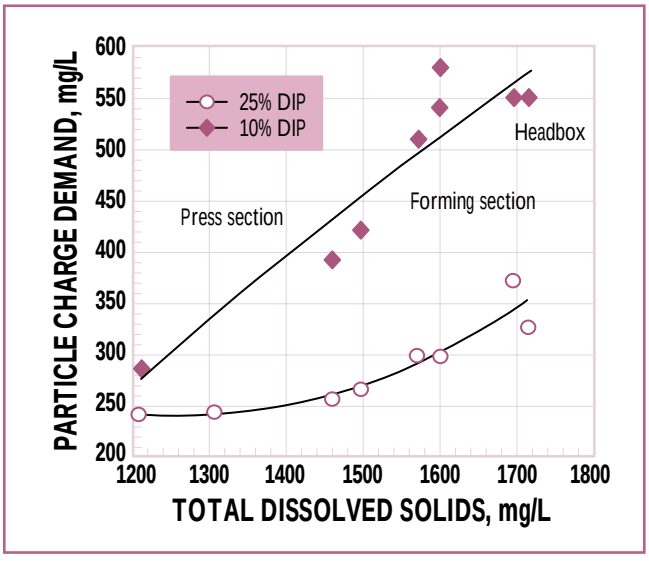
4 4To investigate further the relationship between high ash colloids in the press section and machine runnability problems, we ran a trial to evaluate the effect of DIP content on the ash levels at different points in the paper machine. **Figure 4** shows the significant increase of the ash content of the suspended substances with increasing DIP ratios in the different areas of the paper machine. With increasing recycled furnish, the ash content of the suspended solids increases while the total suspended solids remain



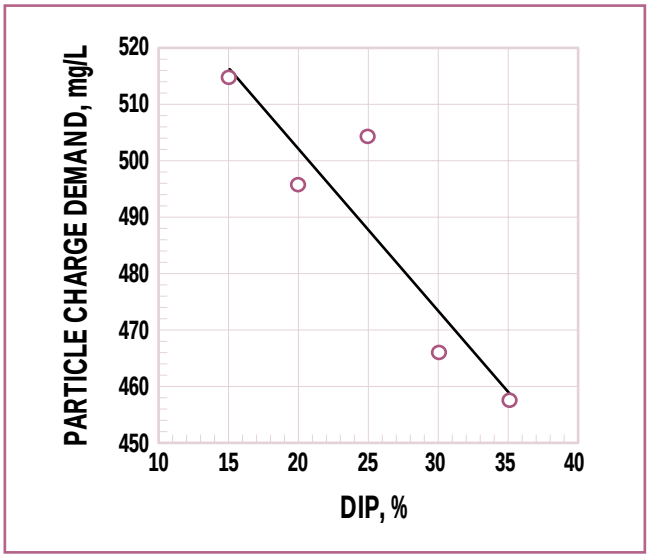
6. Dissolved solids vs. suspended solids along the paper machine for five different runs in which the amount of recycled pulp varied over the range 15–35%



7. TDS with varying DIP at the multifoil shoes, the fourth press, and as a difference between the multifoil and the fourth press



8. Total cation demand measured by titration for polymeric retention aid vs. TDS with two levels of DIP

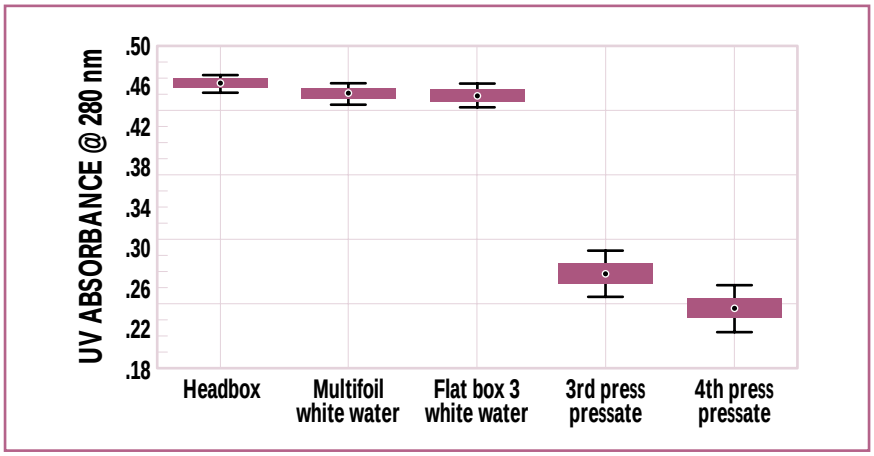


9. Total cation demand at the headbox vs. percentage of DIP indicating that most anionic components originate from TMP

constant. This trend is much greater in the press section than in the forming section. The large increase in the ash amount in the press section at higher amounts of DIP suggests that retention mechanisms by flocculation or filtration are substantially impaired by the increase in ash and the shear forces in the machine. Retention by deposition will normally be favored over flocculation in a high shear environment. Neither process appears very efficient here.

The clay retention problems shown here agree with a flocculation retention mechanism with limited capacity. At pH values between 4 and 5, clay should have a negative face and a positively charged edge. Retention of clay by flocculation using polyethylenimine occurs by an electrostatic rather than a polymer bridging mechanism *(33)*. While the polymer must cover only a small portion of the clay to reach the isoelectric point, the anionic components in the TMP appear to compete effectively for polymer as shown by Alince *(23)*.

We can now formulate a picture of the papermaking process in which the forming wire selectively retains fiber and flocs. Filtration can then effectively remove fines and colloidal material including pitch particles as the forming sheet con-



10. Variation of the UV absorbance at 280 nm of the dissolved solids along the paper machine showing values as an average of five different runs in which the amount of recycled pulp varied over the range 15–35%

solidates. In the press section, white water appears composed of low-charge fines, clay, and pitch. Without dominating highly charged species, these may flocculate readily and lead to deposition problems.

Dissolved solids

Figure 5 shows the TDS for machine zones for five runs on a single day with the amount of recycled pulp at 15–35%. In contrast to the suspended solids that decrease most substantially in the forming section, the dissolved solids decrease most in the press section. The variation shown by the standard deviations in Fig. 5 depends partly on the amount of recycled furnish. **Figure 6** shows the variation of dissolved solids concentrations vs. suspended solids concentrations at different points in the paper machine. This illustrates the importance of dissolved solids removal in the press section. Increasing web consistency effectively initiates interactions that retain dissolved solids.

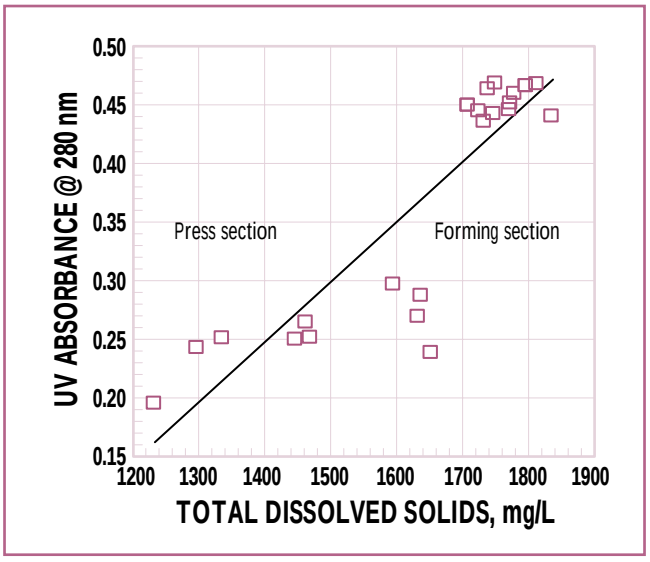
The variation in the points shown in Fig. 6 corresponds to the variation in Fig. 5 that again partly depends on the DIP furnish. These systematic differences lead to improved retention of dissolved components as the DIP increases from 15% to 35%. **Figure 7** shows that the dissolved solids levels increase slightly at the multifoil shoes and decrease at the fourth press. The difference in the dissolved substances concentration between the forming and press sections appears to increase modestly with increasing amounts of recycled pulp. One interpretation of this observation is that there is an increase in retention of dissolved components as the sheet forms with addition of more recycled furnish.

Let us now examine which dissolved substances are removed selectively from the white water during sheet formation. We will consider components including salts and dissolved organic materials such as fatty and resin acids, lignans, and lignin derivatives.

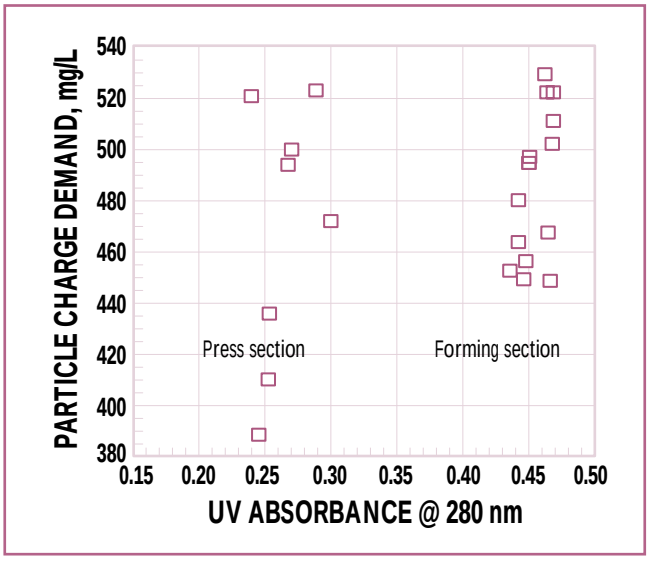
Within the paper machine, cationic charge demand strongly correlates with TDS as **Fig. 8** shows for trials at 10% and 25% DIP. The trends in Fig. 8 reveal that concentrations of dissolved anionic components in the white water decrease beginning midway through the forming section. The curvature shown for the points in Fig. 8 corresponds with a greater selectivity for the removal for charged species at higher charge. Obviously the dominant source of anionic components is the TMP pulp. This is because the cationic charge demand is a steep function of the amount of TMP pulp in Fig. 8 and **Fig. 9**. The substantial decrease in the UV absorbance occurring during sheet formation shown in **Fig. 10** also correlates ($R = 0.88$, $p = 0.000$) with the total dissolved solids concentration shown in **Fig. 11**.There is only a small variation of UV absorbing components at different points in the paper machine in Fig. 10.

Although one would expect that the UV absorbing components would be proportional to the amount of TMP in the furnish, the small variation over the 15–35% DIP range may indicate reaching a solubility limit for these substances. Alternatively an interaction between the DIP and TMP dissolved substances enhances the solubility of UV absorbing components. The high affinity of UV-absorbing substances for the paper sheet in the press section is also evident by comparing the concentrations of dissolved solids and UV-absorbing substances as a function of location on the paper machine. Figures 5 and 10 show these, respectively. Although the UV-absorbing components also appear to contribute to the anionic components in the white water, there is a large drop in UV-absorbing components between the forming and press sections that is more substantial than the corresponding drops in dissolved solids or charge.

The differential selectivity in removal of UV-absorbing and charged species becomes clear by examination of the plot of UV absorbance vs. particle charge demand in **Fig. 12**. Interpretation of this figure indicates that a considerable portion of the UV-absorbing components that are selectively removed have low charge at pH values 4.0– 5.0. The onset of removal of these low-charge, UV-absorbing components appears to occur at a discreet point in the paper sheet formation process compared with the removal of charged species or TDS. The anionic components from TMP include hemicellulose, fatty and resin acids, and lignin derivatives. Of the

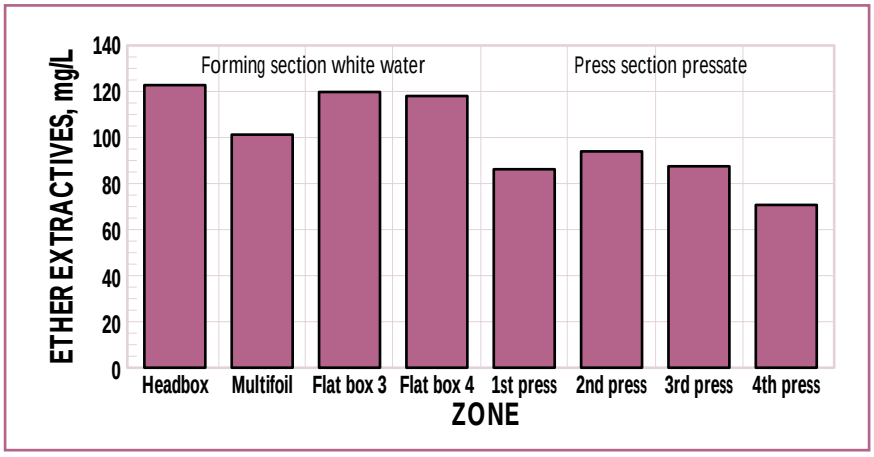


11. UV absorbance at 280 nm vs. TDS with different points in the paper machine identified from a series of runs in which the amount of recycled pulp varied over the range 15–35%



12. UV absorbance at 280 nm vs. cationic charge demand in mg of polymeric retention aid from a series of runs in which the amount of recycled pulp varied over the range 15–35%

components from TMP, some resin acids, the phenolic extractives, and hemicellulose with lignin attached will contribute to the UV absorbance. **Figure 13** shows gravimetric analysis of ether extracts from the white water. The results indicate that the retention of dissolved and colloidal extractives occurs during sheet formation. These removal processes are not as prominent as those for UV-absorbing substances. Extractives that contribute to pitch will increase in the system with pressate recycle. For comparison, we may use a modest lignin absorptivity of 18 L /g/cm *(34)* to calculate that the lignin concentration varies in the paper machine over the range 150–320 mg/L in Figs. 10 and 11. This is much greater than the variation in gravimetric extractives.



13. Gravimetric extractives at eight positions on the paper machine from a trial with 10% DIP and 86% TMP

Using this method to quantify the amount of lignin-like substances in the solution, we find that the loss of lignin constitutes about 17% of the TDS weight loss as the paper sheet forms. Others have identified the importance of interactions of lignin-like components with cationic polymer *(6, 19)*, fiber *(9)*, and fines *(8)*. The small variation in the ICP results in **Table II** and Fig. 11 reveals that the decrease of dissolved solids is mainly due to changes in the dissolved organic substances rather than the corresponding changes in the inorganic salts.

When the TDS decrease 5–10% (80–160 mg/L) between the forming and press sections (Fig. 5), the ether-soluble extractives decrease 25–50% (25–50 mg/L (Fig. 13). The UV-absorbance filtrate decreases 60–70% (Fig. 10). ICP results indicate that the dissolved inorganics, the metals and their salts, in white water are relatively constant with pulp furnish and at the wet end. The principle changes in dissolved solids concentrations along the paper machine are due to the loss of UV-absorbing and anionic organic components that originate from the TMP.

The retention of dissolved substances in the wet web along the paper machine occurs via adsorption. Repulsive or attractive energy and the collision frequency are the principle governing factors *(35)*. Collision frequency depends on the number or concentration of particles. The concentration of fiber increases forty times through the wet end. The interaction between fibers and dissolved and colloidal

	Mean, ppm	Standard deviation	Zone	TDS	UV (280 nm)
Zone			1.00000	-.83506	-.85084
			p<0.000	p<0.000	p<0.000
Na	177.905	19.2481	-.80271	.91805	.79617
			p<0.000	p<0.000	p<0.000
K	20.590	14.5710	.28639	-.13248	-.32970
			p<.175	p<.537	p<.116
Ca	43.543	2.3784	-.58977	.68098	.52096
			p<.002	p<0.000	p<.008
Fe	.285	.2695	.86990	-.93530	-.94008
			p<0.000	p<0.000	p<0.000
Mg	6.808	.1953	.10989	.01336	-.16250
			p<.601	p<.949	p<.438
Mn	1.723	.1249	-.67124	.83089	.65052
			p<0.000	p<0.000	p<0.000
Ba	.239	.0182	-.70519	.85262	.74246
			p<0.000	p<0.000	0<0.000
S	177.810	18.9199	-.28908	.51475	.25635
			p<.161	p<.008	p<.216
Al	.925	.3972	.53385	-.66739	-.60910
			P<.006	p<0.000	p<.001
B	7.256	.9455	-.59878	.60607	.62222
			p<.002	p<.001	p<.001
Si	7.438	.7748	-.03480	-.09867	-.00245
			p<.869	p<.639	p<.991
TDS	1675.143	173.9581	-.83506	1.00000	.88242
			p<0.000	p<0.000	p<0.000
UV, abs @ 280nm	.385	.1085	-.85084	.88242	1.00000
			p<0.000	p<0.000	p<0.000

II. Mean values and correlations between paper machine zone (headbox, multifoil shoes, flat box, #3 press, #4 press), TDS, and UV absorbance at 280 nm

materials therefore enhances greatly as the sheet reaches the press section. Components with low charge such as nonionic hemicellulose and lignin components will preferentially benefit from the increased interaction from the concentration gradient. Wearing *et al.* have shown that changing pulp consistency may substantially shift the thermodynamic equilibrium between dissolved and adsorbed states *(9)*.

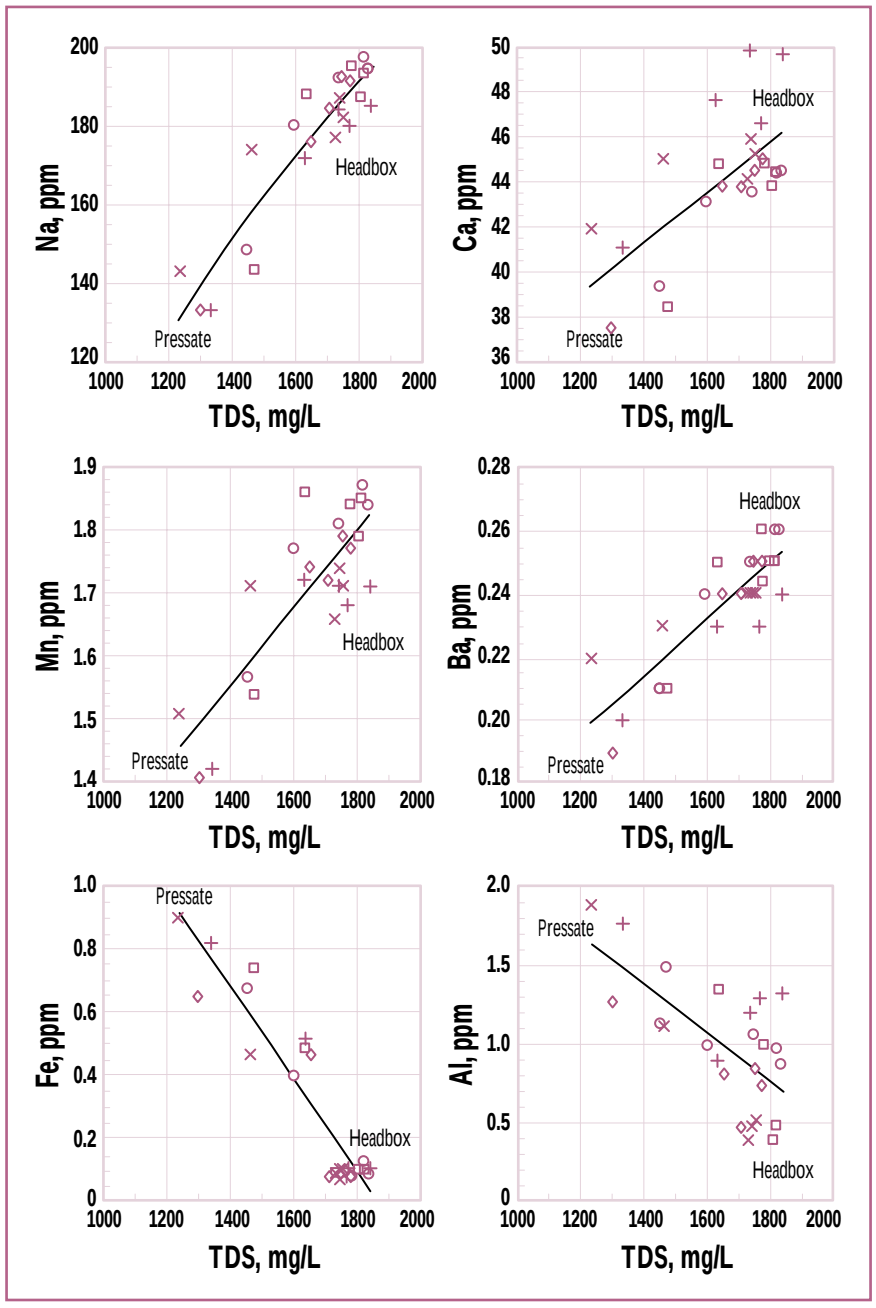
The selective removal of anionic components in the press plays a small but statistically significant role in determining the cation balance in the white water. To investigate the potential role of the paper sheet in removing inorganic electrolytes from the white water, we performed statistical analysis using multiple regression and cluster analysis to identify which dissolved components are selectively removed during sheet formation. Simple linear regression between variables for metals, UV absorbance at 280 nm, and TDS indicated that Si, Mg, S, and K did not correlate with TDS or UV absorbance. Na, Ca, Fe, Mn, Ba, Al, and B did correlate with TDS and the UV absorbance using the regression coefficients and p values. Aluminum and iron negatively correlated with UV and TDS. Table II shows these results. **Figure 14** shows metals that strongly correlate with TDS. K, Mg, and silicates (Si) did not separate by k-means cluster analysis ($p > 0.1$) for the two clusters that corresponded to the press and forming sections. All other variables clustered with p values less than 0.02. A forward, stepwise, multiple, linear regression of all metals and UV to fit TDS rejected S, B, and Si. All these had p values greater than 0.6 with low regression coefficients. Given the metal profile shown in Table II, Na, Ca, Mn, and Ba will stay in the sheet as it consolidates. Al and Fe will stay in the white water. There is no influence on Si, Mg, and K values.

The negative correlation between aluminum and iron values and the TDS may show that cationic polymer displaces some tightly binding cations from pulp. Strazdins previously reported that increased cationic polymer levels displace Ca^{2+} from the pulp *(27)*. Our results do not conform to the analysis of Alexander and Dobbins for substantive and nonsubstantive ions *(29)*. Analysis without accurate models that properly consider the principal concentrations, dissociation constants, and solubility constants will inevitably be difficult to explain. The correlation between sodium levels and TDS is then more a result of the high sodium levels that compensate

for the high dissociation constant.

Examination of the small variations of inorganic components for the paper machine furnish and machine location—compare data in Fig. 14—may yield further insight into potential problems with increased amounts of recycled pulp. Calcium levels were approximately 40 ppm or about 1m*M*. A weak correlation exists with the amount of recycled furnish contributing to an approximate 6% increase in concentration between 15–35% DIP. Recycled pulp contains calcium carbonate. This acts as a source for dissolved calcium that may contribute to the onset of colloidal stability at these levels *(36)*. Sulfur used as SO_2 for pH control in the mill increased in concentration approximately 10% in the forming section. It decreased in the third and fourth press. (Table II provides summary statistics.) The variation in sulfur concentrations provides the best explanation for the overall change in retention and concentrations of dissolved solids shown in Fig. 7.

A decrease in the sulfur at the fourth press—again approximately 10%—accompanies the modest increases in sulfur in the forming section as a function of DIP—approximately 10% over the 15–35% range. At this point, we observed calcium sulfite and calcium sulfate deposits on the third and fourth press of this machine. We identified modest increases in Fe, Al, and Si ions at the limit of the reliability of our data. At this point, the variation in concentrations is near experimental error. Correlation coefficients between 0.65 and 0.97 indicated that Na, Mn, Mg, and Ba decreased as a function of recycled pulp between 5% and 10% over the range of 15–35% DIP. All other ions showed no correlation.



14. Inorganic ions vs. TDS for various levels of DIP at the headbox, multifoil shoes, flat box no. 3, press no. 3, and press no. 4

CONCLUSIONS

The retention and removal of suspended solids along the paper machine occur by flocculation, deposition, and filtration. A comparative evaluation of the removal of dissolved and colloidal substances in this paper machine demonstrates that clay, inorganic salts, and extractives show inefficient removal from white water compared with anionic species and UV-absorbing substances. Insight into the response of the system comes from the substantial decrease in the concentrations of charged and UV-absorbing components and the small change in clay, extractives, and inorganic salts as the sheet forms.

From this response during sheet formation, we expect that the white water system can accommodate changes in cationic charge demand

KEYWORDS
Ash content, bibliographies, deinked stock, dissolved solids, forming sections, newsprint, newsprint machines, paper machines, press sections, reclaimed fibers, removal, retention aids, stock preparation, suspended solids, thermomechanical pulp, white water.

and UV-absorbing components. Extractives, clay, and inorganic substances may accumulate in the white water because they are difficult to remove during sheet formation. This is normal for components not well retained. With time and between runs, concentrations of clay, extractives, and inorganic salts accumulate more than the anionic substances and UV-absorbing components.

In the high-shear environment of a high-speed paper machine, flocculation mechanisms for the retention of fine clay from secondary fiber lead to low ash retention. This results in high ash white water in the press section or ash buildup in the white water over time. The portion of inorganic suspended solids arising principally from clay components of recycled furnish increases dramatically through the paper machine and with greater amounts of recycled pulp. The portion of charged components decreases substantially over the same increase in recycled fiber. The resulting large swings of ash and particle charge demand (PCD) with increasing amounts of recycled furnish are the keystones of the retention problem.

Removal of extractives in the sheet is higher in the press section than in the forming section. It is low compared with the removal of UV-absorbing or anionic components. The extractive substance also appears to accumulate over time in the paper machine. UV and charge titration results indicate that dissolved anionic components including lignin-like substances arise primarily from TMP. They are selectively retained in the forming and press sections. Increasing amounts of recycled furnish correlates to increased concentrations of Fe, S, and Ca and to decreased concentrations of Na, Mn, and Ba in the white water or pressate as the sheet consolidates.

With the removal of dissolved components in the press section, the pressate concentration of the inorganic ions of Na, Ca, Mn, Ba, and S decrease. The concentrations of dissolved iron and aluminum in the press section increase relative to the forming section white water. The selective removal of anionic components and the corresponding release of highly charged cations into the pressate (Al and Fe) during the sheet formation strongly suggests that interactions governed by the cationic polymeric retention aids become increasingly important during sheet formation and pressing. This point should be further investigated in the future. Retention and removal of the different white water components considered in this paper should strongly depend on the retention aid system. The difficulty is to design a retention aid program that can manage both a wide range of components (clay, extractives, and hemicellulose) and the substantial variation in manufacturing conditions necessary to produce more than one product. **TJ**

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