Combined effect of fiber fines and dissolved organics on tissue properties

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ABSTRACT *The quality of tissue is influenced by contaminants that may be present in the white water. Fines and dissolved organics are the main cause of trouble in the manufacturing process. In this work, the quantitative effects of these components on tissue properties were studied. Chemithermomechanical pulp (CTMP) fines and a mixture of xylan, lignin, and resin acid were added to handsheet furnishes. Strength properties, absorbency rate, and formation of handsheets were measured. Fines and organics have an impact on these properties, especially wet strength and absorbency. Resin acid and lignin are the organic contaminants responsible for the greatest effects.*

KEYWORDS
Absorptivity
Closed systems
Fines
Physical properties
Tissue paper
Toweling papers
White water

Fines and dissolved organic and inorganic contaminants have important influences on paper quality (*1*, *2*). Because of tissue papers' special characteristics of low basis weight, low strength, and high absorbency, the impact of fines and dissolved organic contaminants on tissue should be considerable.

The escalating costs of wastewater treatment is promoting an increased use of closed water systems in paper manufacturing, which makes it important to understand the influence of built-up contaminants on the final product. Closing the white water system increases the concentration of dissolved organic and inorganic contaminants as well as fines (*3*). The pertinent literature indicates that although dissolved electrolytes can affect strength properties, organic compounds have a more important effect (*1*). In general, fines influence strength properties, opacity, self-sizing arising from higher concentrations of extractives in fines, and formation (*4*). However, there is a lack of documentation about the effects of these contaminants in tissue paper manufacturing. Neither the combined effects of fines and dissolved contaminants nor the effects of organics on chemical additives are well documented.

Our primary objective in this research was to quantitatively establish the influence of dissolved organics and fines on tissue properties. A second objective was to determine possible interactions between fines and dissolved organics that could have some importance to tissue properties.

CTMP fines generated from beaten pulp and a mixture of 70% xylan, 20% lignin, and 10% resin acid were used to simulate fines build-up and organic contamination. The isolated effect of each organic was established by tests in three sets of handsheets, with 300 ppm of each organic component added to the slurry. The sets of handsheets were prepared using a fixed amount of 60% northern softwood kraft (NSK) and different concentrations of CTMP as received and CTMP fines to complete the slurry composition.

This experimental design has the normal limitations of a handsheet study in reproducing commercial paper machines. Effects of headbox design, table and vacuum dewatering, consistency, yankee adhesion, and creeping may damper some of the observed values. Also, the use of synthesized organics instead of actual organics from the pulp may impart different effects on paper properties. However, the use of synthesized organics makes it possible to establish how each one of them changes the final product.

Results and discussion

Fines characteristics

The length distribution of CTMP fines, generated from as-received and from beaten pulp, was measured using the Kajaani LS-100 Fiber Length Analyzer. Both types of fines have similar length distributions and present a fibrous form, resembling cut fiber. The water retention value further confirmed their similarity as indicated by the results: 3.83 for fines from beaten pulp and 3.87 for fines from pulp as received.

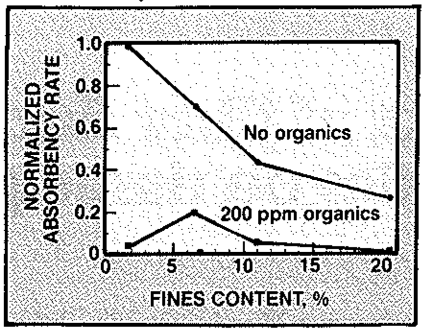
Absorbency rate

The absorbency rate was measured according to the method proposed by Reid (*5*). To provide results that could be easily compared, the measurements

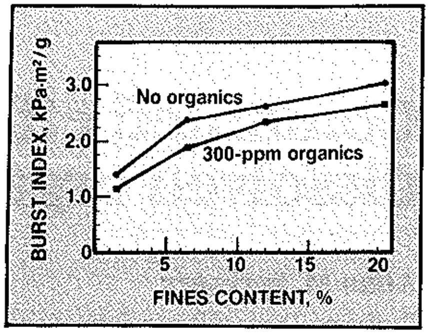
I. The effect of organic contaminants on normalized absorbency rate

Organics ppm	Fines 1.7%	Fines 6.5%
0	1.00	0.70
100	0.06	0.20
200	<0.06	0.29
300	<0.06	0.30

1. The effect of CTMP fines and organics on absorbency rate



2. The effect of organics on burst index



were normalized, dividing each value of the absorbency rate by the measured value of a control handsheet prepared as described in the experimental section.

Dissolved organic contaminants are more important than CTMP fines in determining the absorbency rate. Even a small amount of organics can decrease the absorbency rate to negligible values. **Table I** summarizes the results of the absorbency tests, showing the effect of organics on absorbency for 1.7% and 6.5% fines in the sheet. For sheets with 6.5% fines, there are some interactions among fines and dissolved organics, and there is variation in the proportion of NSK, as explained subsequently. As a consequence, the normalized absorbency rate has an increase from 0.06 for 1.7% fines to 0.20 for 6.5% fines when the concentration of organics is in the range of 100–200 ppm. With further increases in the fines, the absorbency rate decreases rapidly to values in the range of 0.08 to 0.01. Without organics, the absorbency rate decreases in the range of 1.7–20% CTMP fines in the sheet (**Fig. 1**).

The adopted procedure to prepare the handsheet causes an increase in the concentration of NSK in the sheet. Since this pulp has a greater absorbency rate than CTMP, it could be possible to experience a constant absorbency rate, in which case there would be a balance of effects of fines and long fibers, or even an increase in absorbency, as occurred in the case of organics addition. Because this test showed a steady decrease in the absorbency rate when fines are added, it is safe to conclude that an increase of fines in the sheet causes a decrease in the absorbency rate.

Resin acid and lignin are the organics that cause the decrease in absorbency rate. The resin acid made the sheet completely nonabsorbent, acting as a sizing agent, and the lignin decreased the normalized absorbency rate to 0.15. Xylan increased the absorbency by 15%, but even though the mixture of organics contained 70% of this component, the effect of the resin acid and lignin is predominant.

II. The effect of organics contamination on strength properties

Contaminant	Burst index, kPa·m²/g	Dry tensile index, kg·m/g	Wet tensile index, kg·m/g	Wet:dry tensile index ratio
Control	1.15	1.78	0.41	0.23
Lignin	0.86	1.66	0.10	0.06
Resin acid	0.57	1.19	0.47	0.39
Xylan	1.00	1.79	0.39	0.22

Concentration of organics = 300 ppm.

The effect of fines and organics on dry strength

In general, organic contaminants decrease strength properties, while fines increase them. The increase of strength with the addition of fines is also partially caused by the increase in the proportion of long NSK fibers. As an example, the burst index was plotted in **Fig. 2** as a function of fines for handsheets without organics and with 300 ppm of contaminants. There is an average decrease of 13% in this index when organic contaminants are added. Tests to establish the effect of a single organic component on the burst index indicate that resin acid is responsible for a decrease of 50%, that lignin is responsible for a decrease of 25%, and that xylan causes a decrease of 13%, as compared to the control handsheet (**Table II**). For this experiment, three sets of handsheets were prepared, with the addition of 300 ppm of one of the contaminants in each set.

A simple linear model to evaluate the effect of each one of the organics was used (*1*). Applying the model to the mixture containing 210 ppm of xylan, 60 ppm of lignin, and 30 ppm of resin acid, the resultant decrease by the addition of effects is 19%, compared to the measured value of 15%. This evaluation indicates that, pertaining to dry strength, the interactions among organics are few or are nonexistent.

For the dry tensile index, an average decay of 9% was observed when the 300-ppm mixture of organics was added. Again, resin acid causes most of the decrease—33% when used alone at 300 ppm (Table II).

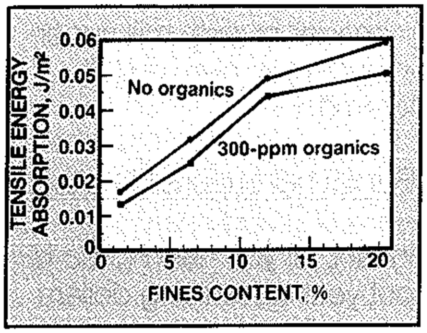
The tensile energy absorption increases with the amount of fines and is decreased by the addition of organics contaminants (**Fig. 3**). This effect is a direct response to the variation in dry tensile strength for fines and organics addition. The difference between the two curves is almost constant over the range of fines from 1.7% to 20.5%.

Lignin decreases the "effective length" of the fiber (*6*); that is, the short span test for fiber length determination shows a decrease when lignin is added to the fiber. Only when fines are present in the slurry was this effect observed. As expected, fines affect the average length of the pulp (**Fig. 4**).

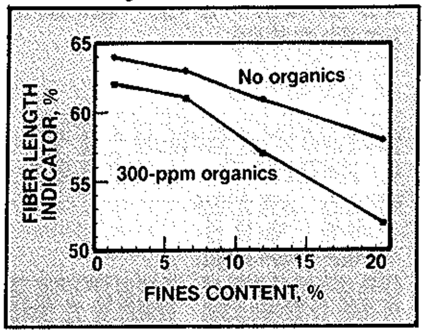
Neither fines nor dissolved organics affect the zero span tensile strength. The results of this test are scattered around the average value of 5.4 kg, with a standard deviation of 0.20 kg.

The action of fines to increase strength is explained by the increase in interfiber bonding, as indicated by the fiber bonding indicator (FBI).

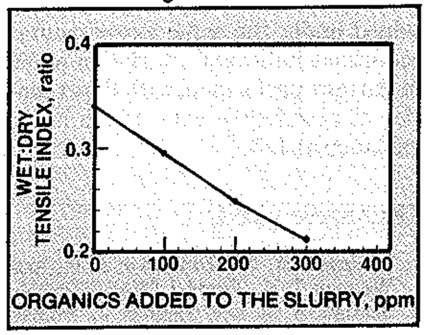
3. Tensile energy absorption



4. Fiber length indicator as a function of fines and organics



5. The ratio of wet:dry tensile strength as a function of organics



This index is evaluated using measurements of short span tensile strength. The FBI rises from an initial value of 7% for 1.7% fines to 41% when fines reaches 20.5%. Since fines promote the bonding, this test indicates that this component is more important to the increase in strength than the increase in the proportion of NSK pulp. Long fibers alone tend to form fewer bonds. Contamination by dissolved organics does not affect this index at a statistically significant level.

Lignin reduces the interfiber bond strength per unit area, probably as a result of sorption onto fiber surfaces (*7*).

The effect of fines and organics on wet strength

The increase in dry strength imparted by fines is also observed in the wet strength, which has the same rate of increase as the dry strength. The ratio between wet and dry tensile strengths remains constant and equal to 0.34 when fines are added and dissolved organics are not present. With the addition of organics, there is a greater rate of decay in wet strength than in dry strength (**Fig. 5**).

This detrimental effect may be a response to interactions between dissolved organics and the wet strength additive which has its efficiency diminished. The experiment to establish the effect of a single organic contaminant indicates that lignin is responsible for this decay, with a decrease of 76% as compared to the control sheet. The sizing action of the resin acid prevents any effect of this component on the wet strength, which even shows an increase of 15%. Xylan can be considered neutral, since the difference between the wet tensile strength for the control sheets and the sheets containing xylan is within the experimental uncertainty.

Formation

Using an M/K Systems Microformation Tester and Floc Analyzer, formation and floc size were measured by the local variation of optical density.

CTMP fines provide a steady increase in formation, from an index equal to 2.0 to a value equal to 4.4. This improvement can be seen as the action of these fines as fillers, closing the porous web and then providing a more uniform sheet. This trend is not consistent with what was observed for NSK fines in a research performed to differentiate the effects of CTMP and NSK fines. Dissolved organics are neutral to formation, which also means that they have little effect on the flocculation state and fines retention.

Conclusions

Organics are detrimental to most tissue properties, and their presence should be avoided in the white water system. Even a small amount of organic contamination can decrease the absorbency rate to negligible values. Resin acid has a sizing effect and is the main source of decrease in absorbency rate. Xylan caused a small increase in the absorbency rate. Fines and an increase in the proportion of long fibers may interact with organics to increase the absorbency rate, but this effect was insufficient to restore the original absorbency.

Strength properties, in particular wet tensile strength, are adversely affected by organic contamination. Fines have a positive action on these properties.

Xylan is neutral or has little effect on tissue properties. Lignin and resin acid account for the detrimental results.

Experimental procedures

Fines and organics preparation

CTMP fines were collected from pulp beaten in a laboratory Valley beater. The pulp was fractionated using a Bauer-McNett classifier, and fines were collected on a cloth. Four percentages of fines in the slurry were used: 1.3%, 22.1%, 32.4%, and 43.8%.

Xylan and lignin in aqueous solution were added to the pulp during the preparation of the slurry and to the proportioner of the handsheet machine. Indulin C was the lignin used. Resin acid was dissolved in a solution of 5% NaOH prior to its addition to the slurry and proportioner. Three concentrations of organics were applied—100, 200, and 300 ppm, with a composition of 70% xylan, 20% lignin, and 10% resin acid. Four sets of handsheets with the four percentages of fines were manufactured without the addition of organics.

Handsheet manufacturing

In one complete 4 × 4 factorial design experiment, four sets of handsheets were manufactured, one without organics addition and three sets with each one of the contaminants added separately. The furnish consisted of 60% NSK and 40% CTMP. CTMP fines were added to the original pulp. Handsheets of 26.9 g/m² were produced in a 8 × 8-in. Noble and Wood mold without pressing the sheets before the drying operation, so that a tissue could be simulated. Distilled water with 50 ppm hardness in the form of added calcium chloride was used for all phases of handsheet manufacturing. Wet and dry strength additives were used. For comparison purposes, handsheets made with the pulp as received, without addition of organics of fines, were considered standards.

Never-dried handsheets were fractionated to measure fines retention.

Comparison of measurements obtained under the same experimental conditions indicates a variation of 5% in the tests performed, with the exception of absorbency rate, which has a variation of 10%.

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