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The Influence of Newspaper Aging on Optical Properties of its De-Inked Pulp

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Abstract

The ever increasing volume of waste newspaper indicates the importance and availability of this paper for recycling. However, aging of the print, especially offset print, plays an important role in recycling, which requires additional consideration. The effects of aging and sodium hydroxide on de-inking of old newspaper is investigated.

In all, 4 natural aging periods (0, 4, 8, and 12 months) and 5 concentrations of sodium hydroxide (0%, 0.5%, 1.0%, 1.5%, and 2.0% on bone-dry (BD) weight of the paper) were employed to study the de-inking of offset printed newspaper. Optical properties of recycled paper, including brightness, yellowness, and absorption coefficient, were measured.

The results indicate that the treatment of non-aged newspaper with 1.5% sodium hydroxide produced the best de-inking. Aging newspaper for 4 months and longer decreased the brightness of de-inked pulp and increased the absorption coefficient, whereas higher doses of sodium hydroxide increased brightness and decreased the absorption coefficient. No significant difference was observed between 1.5% and 2% sodium hydroxide. Aging decreased yellowness and sodium hydroxide increased it.

Key words: Aging, Absorption Coefficient, Brightness, De-inking, Yellowness

Introduction

The need for higher rates of wastepaper utilization has spurred extensive research and development in recycling various grades of wastepaper. Old newspaper recycling is unique, because printing technologies are still developing and new inks are introduced. Reusing old newspaper requires de-inking, which is influenced by many factors, among which the most important are ink formulation, ink curing, and print age. Even though most ofresearch has been concentrated on the effect of ink formulation on de-inking, more attention should be given to the influence of print age.

Jordan et al. (1995) indicated an almost 2% decrease in brightness after 2 years of aging for Canadian newspaper stored in archives. Lunabba (1996) reported that offset printed newspaper must be recycled within 4 months of publication, otherwise de-inking will be difficult. He also mentioned that artificial aging creates more difficulties than natural aging. Sjostrom and Calmell (1997) focused their research on the effect aging had on pulp brightness by recycling 3 grades of paper that contained similar furnish of TMP, bleached, or unbleached kraft pulps. De-inked pulp from aged paper showed much

lower brightness than un-aged paper. In their work, photographic analysis of the ink particle size in pulp and ink sludge showed that aging reduced the size of the ink particles. They suggest that the absorption coefficient of pulp measured at the wavelength range of 400-700 nm could be a good indicator of ink remaining in recycled pulp. Castro et al. (2002) studied the influence of aging on the oxidation of ink polymer chains and reported that the existence of vegetable oils in offset printing inks causes more oxidation and difficulty in de-inking old prints, which will reduce the brightness of the de-inked pulp.

Galland et al. (1997) suggested that a combination of flotation and washing for de-inking of flexographic and laser prints is more effective than either one alone. Also, Kaul (1991) suggests the use of water-based solvents containing surfactant for dispersing inks in old newspapers. Renders (1993), Gurnagul (1995), and Pauck and Marsh (2002) indicated the positive impact of sodium hydroxide on ink removal, as well as the important role of sodium silicate for dispersing ink. Marichildan et al. (1993) expressed that soaps containing fatty acids, with or without a small number of double bonds in the main chain, possess greater ability to remove ink, and Mak and Steven (1993) indicated that the chain length of fatty acids and the number of double bonds strongly influence flotation de-inking.

The important effect of print age on de-inking efficiency and the need to improve local waste newspaper recycling process necessitated performing this research.

Experimental

Old newspapers offset printed on Canadian paper were used. The basis weight, opacity, and brightness of this paper were 48.8 g m^{-2}, 95%, and 60%-62%, respectively. These old newspapers were collected from the archive (natural aging) 0, 4, 8, and 12 months after printing. Sodium hydroxide was applied at concentrations of 0%, 0.5%, 1.0%, 1.5%, and 2%, according to the BD weight of the paper. Other pulping and flotation variables are given in Table 1.

All experiments were performed in the R & D of LATIF Pulp & Paper Co. Laboratory disintegration and de-inking were carried out on 20-g samples. Each wastepaper sample was first cut into small pieces, which were transferred into a disintegrator and the required amount of chemicals and sufficient water were added to make 4% consistency pulp slurry. After slushing, the pulp slurry was de-inked using flotation, followed by washing on a 200-mesh screen. Each experiment was repeated 4 times. Additionally, control samples were prepared from pulping newspapers of different ages and without additional processing.

Handsheets were prepared and optical properties were measured according to TAPPI test methods, as follows:

- Handsheet making : T205 sp-95
- Brightness : T452 om-98
- Absorption Coefficient : T425 om-96
- Yellowness : T524 om-94

The absorption coefficient of pulp was determined at 457 nm. As mentioned before, according to Sjostrom and Calmell (1997), the absorption coefficient can be used as a good indicator of residual ink in pulp. All chemicals used were purchased from Merck.

Table 1. Constant variables in pulping and flotation.

Pulping Variables			Flotation Variables		
Hydrogen Peroxide	(%)	1	$CaCl_2$	(%)	1
Sodium Silicate	(%)	2.5	Consistency	(%)	1
Sodium Stearate	(%)	1	Temperature	°C	20-25
DTPA	(%)	0.2	Time	min	20
Consistency	(%)	4			
Temperature	°C	50			
Time	min	20			

All percentages are based on bone dry (BD) paper weight.

Results

The results of this study were statistically analyzed using a completely randomized design and Duncan's new multiple range test was used to categorize the averages. The average results for each optical property and the comparison of the averages are summarized in Table 2. Table 2 also shows the results of the measurement of de-inked control samples of different print ages. It was observed that the optical properties of the control samples were of lesser quality than those of the treated samples. Table 3 shows the results of the analysis of variance.

Table 4 shows the correlation between optical properties of recycled newspaper. The correlation between brightness and absorption coefficient was – 0.865, which is a good value; however, for other properties the correlation was not very favorable.

Table 2. Average results of the optical properties and their comparison.

Treatment	Treatment Variables				
	Aging(Month)	NaOH (%)	Brightness (%)	Yellowness Index	Absorption Coefficient(m^2 kg^{-1})
1	0	0	54.568 (c)[a]	9.72 (j)	7.472 (k)
2		0.5	54.328 (c)	11.542 (g)	8.356 (j)
3		1	55.540 (b)	12.62 (ef)	6.058 (l)
4		1.5	56.320 (a)	14.864 (b)	5.518 (l)
5	4	2	56.584 (a)	16.898 (a)	4.822 (m)
6		0	45.558 (h)	12.708 (e)	8.928 (hij)
7		0.5	44.126 (k)	13.298 (cd)	9.214 (ghi)
8		1	43.688 (l)	13.200 (d)	10.294 (de)
9		1.5	45.648 (h)	14.906 (b)	9.672 (efg)
10		2	47.064 (e)	16.772 (a)	7.28 (k)
11	8	0	46.136 (g)	9.894 (j)	9.666 (efg)
12		0.5	45.850 (gh)	9.776 (j)	9.386 (fgh)
13		1	46.396 (f)	12.324 (f)	8.970 (hij)
14		1.5	45.022 (j)	14.882 (b)	8.942 (ij)
15		2	47.888 (d)	13.132 (d)	8.664 (ij)
16	12	0	43.976 (kl)	10.894 (h)	10.120 (de)
17		0.5	44.126 (k)	10.614 (hi)	10.730 (cd)
18		1	45.204 (ij)	13.136 (d)	10.326 (de)
19		1.5	43.716 (kl)	12.452 (ef)	9.898 (cf)
20		2	46.486 (f)	13.544 (c)	9.034 (ghij)
21	Control 1 (no age)	-	42.532 (m)	9.420 (k)	13.194 (a)
22	Control 2 (4 months)	-	41.374 (n)	10.400 (i)	11.948 (b)
23	Control 3 (8 months)	-	45.022 (j)	8.522 (l)	13.200 (a)
24	Control 4 (12 months)	-	42.192 (m)	9.990 (j)	11.282 (c)

(a) Letters show the Duncan grouping.

Table 3. Analysis of variance of the optical properties.

Property Treatment	Brightness (%)	Yellowness Index	Absorption Coefficient (m^2 kg^{-1})
A	**	**	**
C		**	**
AC	**	**	**

A: aging**;** **C**: caustic soda, **AC:** interaction between A and C.
**Significant at 99% probability.

Table 4. Correlation of the measured properties of the de-inked pulps.

Property	Brightness	Yellowness
Absorption Coefficient	–0.865	0.484
Yellowness	0.176	1

Discussion and Conclusion

De-inking is an essential stage in paper recycling, which removes ink from printed paper and, therefore, increases the brightness of the final pulp, making it suitable for the production of paper.

According Rahmaninia et al.'s previous works, results indicate that aging has a negative effect on both breaking length and fold strength, and in contrast to aging NaOH increased both breaking length and fold strength. Also, floatation, followed by one step washing on 200-mesh screen had a negative effect on breaking length and fold strength.

In the present study we concentrated on optical properties. The comparison between the optical properties of the control and treated samples shows the beneficial effect of this process in paper recycling. The results summarized in Table 2 show that the brightness of the control samples was lower than that of the treated samples and that the coefficient of light absorption of the control samples was higher than that of the treated samples. The effect of treatment on pulp yellowness was insignificant and the yellowness of both the control and treated samples was almost the same; however, the application of sodium hydroxide may cause the phenomenon of yellowness reversion. Applying an additional washing stage in pulp de-inking had a positive effect on the optical properties and improved pulp quality.

As seen in Table 3, the effect of each independent variable on the optical properties of de-inked pulp was statistically significant and interaction of the variables was also significant. Increasing the concentration of NaOH improved the brightness and reduced the absorption coefficient of the de-inked pulps, which is in accordance with the results of other researches (Renders, 1993; Gurnagul, 1995) (Figure 1).

Print age also decreases the brightness and increases the absorption coefficient of recycled pulp. The maximum effect was observed between non-aged samples and samples 4 months old. In this case the brightness was reduced from 56% to 46% and the absorption coefficient increased from 8 m^2 kg^{-1} to 12 m^2 kg^{-1} (Figure 1, 2). Lunabba (1996) and Sjostrom, and Callmel (1997) reported the same results.

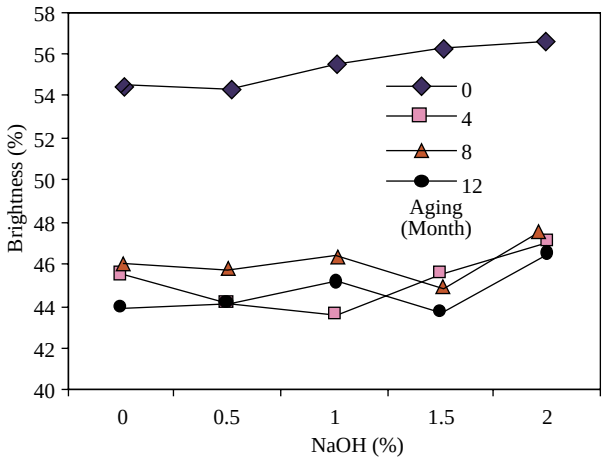

Figure 1. Interaction effect of the variables on the brightness of de-inked pulp.

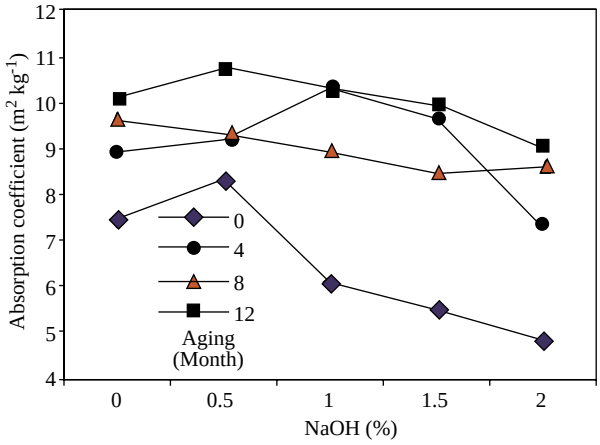

Figure 2. Interaction effect of the variables on absorption coefficient of de-inked pulp.

The detrimental effect of aging on de-inkability of aged newspapers can be attributed to the increase in polymerization and oxidation of alkyd resins existing in the ink formulation, which increases their adherence to the fibers and decreases their dispersability in the de-inking medium.

During hot offset printing the heat applied enhances oxidation and facilitates fast curing of the ink on fibers. Therefore, de-inking such prints is more difficult than with ordinary prints and the final brightness of the de-inked pulp is lower. Castro et al. (2002) observed similar results.

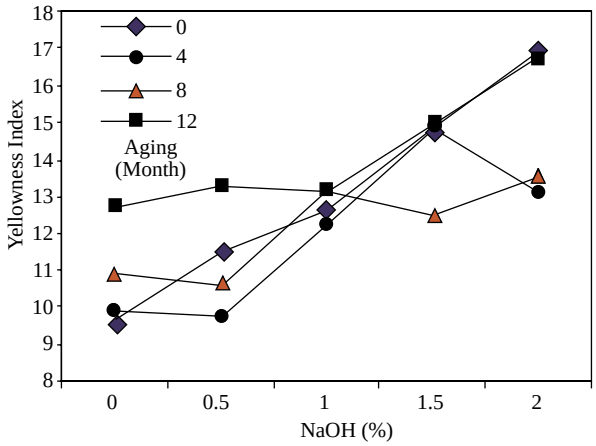

Figure 3. Interaction effect of the variables on the yellowness of de-inked pulp.

Increasing the concentration of sodium hydroxide increases the level of yellowness of de-inked pulp, which can be likened to alkali darkening of NaOH, especially on mechanical paper, such as newspaper (Gurnagul, 1995). Of course, the addition of higher amounts of hydrogen peroxide will prevent further development of this phenomenon. In contrast to our expectation, aging had a positive effect on yellowness. Although yellowness increased after 4 months of aging, as compared to no aging, further aging to 8 and 12 months did not improve yellowness (Figure 3). Such results can be related to the reduction of ink particle size during the de-inking process in samples 8 and 12 months old. These small particles will produce higher coverage on fibers and reduce yellowness.

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