Journal of Korea TAPPI
Vol. 31. No. 5, 1999
Printed in Korea

The Effects of Multiple Recycling on Deinkability, Optical and Physical Properties of Recycled Paper

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ABSTRACT

This study examined the effects of multiple recycling on deinkability and properties of recycled paper from laser computer printout (LCPO).

First, alkaline paper with a 20% printed area was disintegrated by TAPPI standard disintegrator. After dewatering, the pulp was followed by flotation, handsheet making, and drying at room temperature, in order. A sequence of printing, disintegrating, flotating, handsheet making and drying was one recycling cycle and this cyclic treatment was repeated from zero to five times.

The residual ink content in recycled handsheets by SEM-EDXA and Py-GC analyses was increased slightly as recycling number increase.

After five cycles of recycling the ISO brightness of recycled handsheets dropped to about 90% of the original brightness. However, it had a gain of 10% in opacity.

The most physical properties of recycled handsheets were decreased as recycling numbers increase except for tear strength.

1. Introduction

In 1997, approximately 4.53 million tons of wastepaper were collected for recycling in Korea. The collection rate and utilization rate were 56.8% and about 70%, respectively. Probably the most important object for utilizing wastepaper as a raw material in Korea to make paper and paperboard is for economic reason since Korea lacks a primary fiber supply.

Increasing consumption demand for recycled fiber content in most paper products is challenging manufacturers to use lower value raw materials while maintaining their high quality product standards.

Office wastepaper or office mixed waste (OMW) has been a new target of deinking practices for an additional deinked pulp resources because it includes wood-free paper as a major portion. Generally, it was known that office wastepaper contains 56-74% recyclable paper by weight.[1] However, office wastepaper consists of various wastepapers and the most common printing types of these wastepapers are electrophotography and laser printing.

The main problem in recycling office wastepaper is that it is difficult to remove ink (toner) from pulp fibers. For this reason, recycling rate for higher quality paper grades such as office wastepaper is lower than that for toner-free wastepaper.

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Although it has been studied to solve this problem by many researchers, this matter still remains unsettled.

Some of the impact on recyclability would depend on how the fibers were initially turned into paper. During the drying process, the water leaving the lamellae of the cell wall draws them closer together and in some instances the lamellae adhere to one another.[2)]

High yield pulps - for example, TMP, CTMP, etc. - can be recovered the ability to take up water following a drying treatment, while lower yield pulps cannot.[3)] And the properties of high yield pulps were essentially unaffected by the recycling process, whereas the chemical pulps were a 30-40% reduction after four recycles in another study.[4)] It was shown that fiber length and strength were unchanged from repeated recycles, except due to calendering or refining.[5)]

The objective of this paper is to examine the effects of multiple recycling on deinkability and properties of recycled paper under different recycling times using 20% printed laser computer printout (LCPO) wastepaper.

2. Materials and Methods

2. 1 Materials

Alkenyl succinic anhydride (ASA) sized alkaline paper of 68.0 g/m^2 was used in this investigation as an original paper. It was printed by laser printer with a single toner, and each wastepaper was printed to have a 20% printing area.

A sufficiently large number of wastepapers were prepared at the initial preparation so that recycled handsheets could be made after each cycle for various tests.

2. 2 Definition of recycling

The wastepaper was recycled by repeated printing, disintegrating, flotating, handsheet making, pressing and drying as shown in Fig. 1.

The disintegrating was done with TAPPI standard disintegrator according to TAPPI Methods 205 sp-95 at 5% consistency and 50° C for 15 min. The chemicals were then added to the hot soft water in the disintegrator and mixed well before adding the wastepaper furnish. The wastepaper furnish was prepared

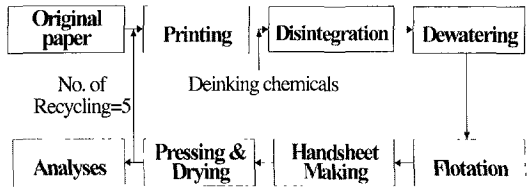

Fig. 1. Flowchart of recyling process.

by tearing the waste paper into small pieces (about 10×10 mm) by hand. Deinking chemicals used were 2.5% NaOH, 3.0% Na_2SiO_3, 1.0% H_2O_2, and 0.35% deinking agent (DI-600R, non-ionic fatty acid type from Kao Corporation) based on oven-dried weight of pulp. After disintegrating, this furnish was dewatered to a 10% consistency and diluted to a consistency of 1% before flotation. Flotation was done in a 8 L capacity laboratory flotation cell at 1% consistency and with 50° C soft tap water for 15 min. After flotation, the accepted pulp was centrifuged to a moisture content of 25%. After the consistency control, recycled handsheets were made at a grammage of 80 g/m^2, and pressed, dried by drum dryer at 150° C.

A sequence of printing, disintegrating, flotating, handsheet making, pressing and drying was one recycling cycle and this

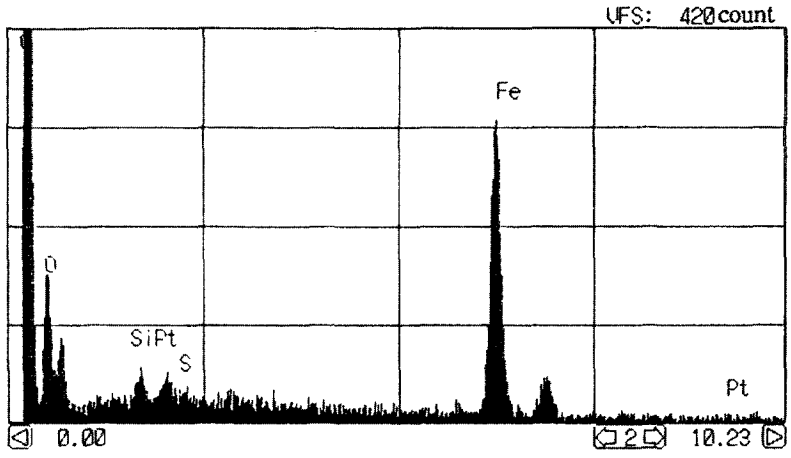

Fig. 2. Energy dispersive X-ray spectroscopy analysis of laser printer ink.

cyclic treatment was repeated from zero to five times.

2. 3 Measurements

Analyses of wastepaper was carried out by measuring the residual ink content in recycled handsheets using analytical techniques such as scanning electron microscope (SEM) equipped with energy dispersive X-ray analyser (EDXA), and pyrolysis-gas chromatography (Py-GC). Measurement conditions of SEM-EDXA were as follows;

-Platinum coating time : 100 sec.
-Scanning electron voltage : 20 kV
-Enlargement : ×40
-Measuring time of EDX : 500 sec.
-Measuring mode : Quantitative mode, P5

And, measurement conditions of Py-GC were as follows;

-Pyrolyzer temperature : 500° C
-Injection temperature : 250° C
-FID detector temperature : 280° C
-Column temperature : 150 → 300° C, 5° C/min

3. Results and Discussion

3. 1 SEM-EDX analyses of laser printer ink, and effect of multiple recycling on deinkability

It was found that the LCPO contained iron (Fe) compound from laser printer ink(toner) by SEM-EDX analyses as shown in Fig. 2. We studied the change in the iron compound content of recycled handsheets by the numbers of recycling. As a result, it was shown that the amount of iron compound was not significant statistically in recycled handsheets. This indicates that the most of Fe compound in LCPO was removed during recycling treatment including flotation.

Recently, the authors have reported that pyrolysis-gas chromatography (Py-GC) is potentially useful for the analysis of trace agents in paper, such as wet-strength resin[6] and neutral sizing agents.[7] And, in this study, the method for determining residual ink content in recycled handsheets were established by means of Py-GC.

Fig. 3 shows the pyrograms of the control paper sample (a), laser printer ink alone (b), waste paper sample (c) and an actual

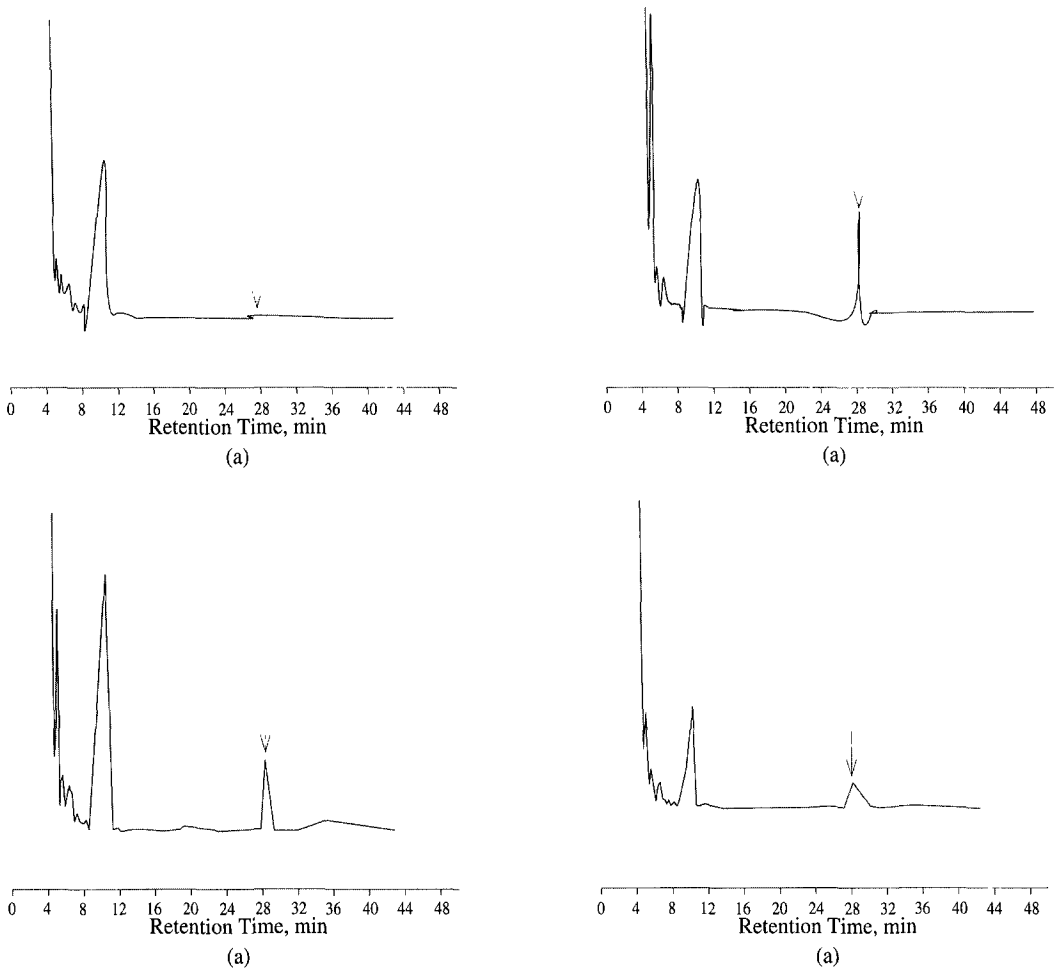

Fig. 3. Pyrolysis-gas chromatograms of original paper (a), laser printer ink (b), wastepaper (c), and recycled handsheet (d).

recycled handsheet sample containing ink particles (d) at 500℃. As shown in the pyrogram of laser printer ink alone (b), a sharp peak at retention time 28 min were observed. This peak was identified as polymers derived from the laser printer ink binder by gas chromatography-mass spectrometry (GC-MS) measurement for this characteristic peak.

On comparing Fig. 3 (c) with Fig. 3 (d), it is apparent that the deinking treatments including flotation affect the peak intensity (relative peak area) of paper sample. Therefore, the intensity of this large peak was used for the determination of the residual toner ink content in recycled paper samples from LCPO. And, we also learned that the relative peak area by Py-GC has a good correlation with the residual ink content in recycled handsheet. The equation for residual ink content is as follows;

Residual ink content (g/g) = Relative peak area × 0.06

Therefore, it was found that the relative peak area by Py-GC is suitable for evaluating the deinkability of recycled handsheets

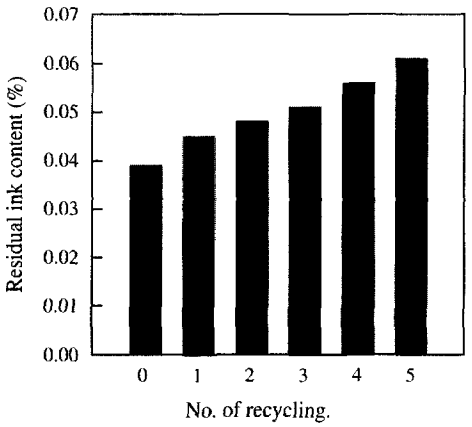

Fig. 4. The change in residual ink content of recycled handsheets by multiple recycling.

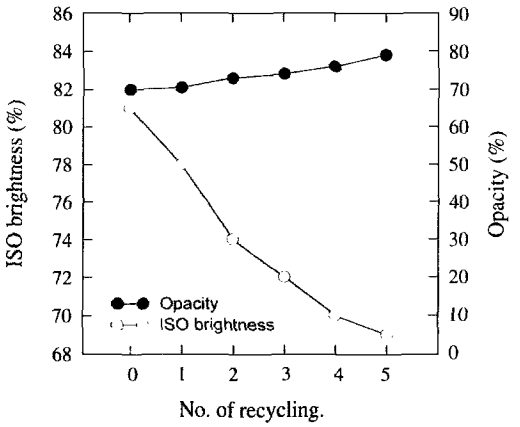

Fig. 5. The changes in ISO brightness and opacity of recycled handsheets by the number of recycling.

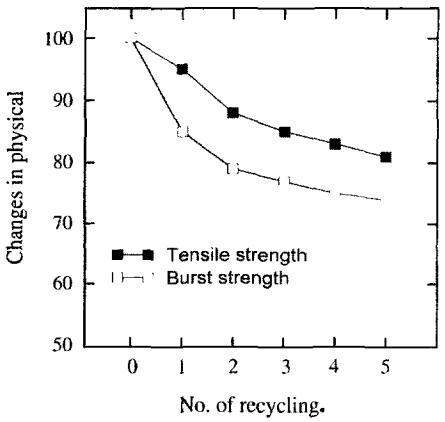

Fig. 6. The changes in physical properties of recycled handsheets by the number of recycling.

from LCPO.

The residual ink content of five times recycled handsheet was higher than that of first one as shown in Fig. 4. That is, the deinkability of recycled handsheets gradually decreased as the addition of recycling numbers as expected. It was reported that the main cause of deinkability decreasing by recycling numbers in non-printed waste paper is the change of characteristics of pulp fiber such as a fiber swelling.[8] However, the laser printed wastepaper was used in this study. This suggests that not only the change of fiber morphological properties but also the cumulative retention of ink particles play the major role in the reduction of deinkability by recycling numbers.

3. 2 The effect of multiple recycling on optical properties of recycled handsheets

The changes in ISO brightness and opacity of recycled handsheets by recycling numbers are shown in Fig. 5.

The ISO brightness is decreased by multiple recycling. It is not yet certain why the brightness of recycled handsheet is decreased during multiple recycling. But, it can be probably suggested that this decreasing originates from both the brightness reduction of fiber itself and the change of interfiber bonding relating to surface condition of fibers. It is also suggested that, perhaps, the ink particles affect the fiber surface inactivation or interfiber bonding capacity.

On the other hand, the greater the recycling numbers, the higher the opacity of recycled

handsheets. The cause of this increase is the hornification of fiber. As mentioned above, the swelling capacity or the flexibility of fibers was lost by recycling, and then the recycled fibers become more brittle. Therefore, inter-fiber bondings are decreased, which brings about the increasing of light scattering coefficients of recycled handsheet. As a result, the opacity of those becomes higher.

3. 3 The effect of multiple recycling on physical properties of recycled handsheets

It is well known that it is difficult for once-dried pulp fibers to restore to their original states. Therefore, paper made from once-dried pulp fibers has lower strength properties than paper made from never-dried pulp fibers.

In this study, besides tear strength, the most of physical properties are decreased as recycling numbers increase. This tendency is the same as that in non-printed wastepaper recycling. It is postulated that ink particles and deinking chemicals did not severely affect the reduction of physical properties of recycled handsheets.

4. Conclusions

The effects of multiple recycling on deinkability and properties of recycled paper can be concluded as follows;

1. The deinkability of recycled handsheets gradually decreased as the recycling numbers increased.

2. The ISO brightness decreased by multiple recycling, but the greater the recycling numbers, the higher the opacity of recycled handsheets.

3. The deinking chemicals did not severely affect the physical properties of recycled handsheets

Acknowledgement

The authors wish to acknowledge Dr. F. Onabe, A. Isogai, and T. Enomae in University of Tokyo for their valuable technical assistance and for many useful discussions.

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