In: Proceedings of the 1995 International environmental conference;
1995 May 7-10; Atlanta, GA. Atlanta, GA: TAPPI PRESS: 445-448; 1995.

ENVIRONMENTALLY SOUND ALTERNATIVES FOR UPGRADING MIXED OFFICE WASTE

Marguerite Sykes
Forest Products Technologist

John Klungness
Chemical Engineer

Freya Tan
Chemical Engineer
USDA Forest Service
Forest Products Laboratory[1]
Madison, WI 53705-2398

Said Abubakr
Superv. Chemical Engineer
USDA Forest Service
Forest Products Laboratory[1]
Madison, WI 53705-2398

ABSTRACT

Mixed office waste paper is a source of high quality fiber that could be reclaimed for use in printing and writing grade paper, However, conventional deinking and bleaching technologies do not effectively remove laser and xerographic toner inks or paper dyes. Residual ink specks and color limit the products in which deinked pulp can be used. Complementary alternatives, enzyme deinking and fiber loading, have been developed at the Forest Products Laboratory to upgrade mixed office waste paper. These new processes are environmentally compatible, affordable, and use equipment typically available in deinking mills. This paper reports the benefits of combining these two green technologies to meet the challenge of upgrading low-value mixed office waste. Benefits of enzyme deinking include effective toner removal, improved effluent quality, increased pulp drainage, cost effectiveness, and decreased electrical energy consumption. Benefits of fiber loading include utilization of waste carbon dioxide from stack gases, extended fiber resource by filler substitution, minimized sludge, and masked residual ink and contaminants.

INTRODUCTION

Mandates for increased recycled content in office paper, escalating tipping fees for landfilling, and public pressure for conserving our forests are compelling reasons to recycle more waste paper, Economic reality has shifted the waste paper source for recycling to the abundant and previously underutilized mixed office waste. Because mixed office waste is an available and inexpensive source of high quality bleached chemical fiber (1), it can be hand-sorted to exclude lower value fiber and debris, leaving a relatively clean pulp furnish. Although xerographic and laser toner inks are difficult to remove, a combination of chemicals and multiple stage deinking and dispersion processes can produce pulp suitable for printing and writing paper, However, current demand for mixed office waste is increasing the cost. To remain competitive, deinking mills will have to deal with a more heterogeneous waste paper furnish. Industry is responding by adding more deinking and bleaching chemicals and energy intensive processes to meet target brightness and cleanliness.

Recycling waste paper has important environmental implications. In addition to conserving valuable fiber, the need for new landfill sites would be decreased. Unfortunately, other environmental problems are often created when conventional technologies are used to reprocess paper printed with advanced technology inks and printing techniques. Recycling generates large quantities of sludge and effluents high in oxygen-demanding material (2). Considerable electrical energy is required to upgrade waste paper, The future of recycling tomorrow's complex waste paper in environmentally sound ways depends upon technologies capable of dealing responsibly with heterogeneous furnishes.

This paper describes two complementary alternatives used by researchers at the Forest Products Laboratory (FPL) to upgrade office waste paper: enzyme-enhanced deinking and fiber loading. These new methods are environmentally compatible, affordable, and use equipment typically available in deinking mills. Commercial enzyme preparations can replace conventional deinking chemicals to remove toner inks (3) In addition to producing a cleaner pulp, enzymes improve pulp drainage during papermaking and may reduce the deinking effluent toxicity and chemical oxygen demand load (4).

BACKGROUND

Fiber loading, a process developed by researchers at the FPL, precipitates calcium carbonate within the lumen, cell walls, and exterior surfaces of pulp fibers (5), In this process, carbon dioxide can be captured from mill stack gases and reacted with calcium hydroxide to precipitate calcium carbonate. Partial internal incorporation of this common papermaking filler results in increased filler retention during recycling, which reduces the quantity of sludge generated. Preliminary experiments have demonstrated that recycled pulp can be fiber loaded, resulting in increased pulp brightness, improved color, and substantially reduced residual ink and contaminants.

Enzyme-enhanced deinking and fiber loading can be combined to produce a high-value recycled pulp from a low-value mixed

[1]The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright.

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

office waste. This paper first examines the benefits of each process separately and then illustrates how they can complement each other to upgrade waste paper. Industrial-scale trials of enzyme deinking on segregated office waste paper, composed primarily of laser printed paper, are scheduled for early December 1994. Deinking effluents and sludge will be evaluated and compared with those from conventional deinking. The deinked pulp will be fiber loaded to demonstrate the additive benefit on paper properties. Results from these trials will be presented at the Tappi Environmental Symposium in May 1995.

DISCUSSION

Enzyme Deinking

Laser and xerographic printed paper are the major components of office waste paper and their use is increasing annually. Laser and xerographic printing use thermoplastic toners that fuse onto fiber surfaces during high temperature noncontact printing (6). These nondispersable inks require special chemical, thermal, and mechanical actions to detach the inks from fibers so that the inks can be removed by flotation-a deinking process that separates hydrophobic ink particles from the hydrophillic pulp fibers. We found that commercial cellulase preparations, or products with a combination of cellulase and hemicellulases, can replace conventional deinking chemicals to release toners from waste paper. Enzyme preparations, when combined with inter-fiber friction of medium-consistency (14%) pulping, help to separate detached ink particles from the pulp slurry by clipping and smoothing pulp fibrils from the fiber surface. Although the activity of most cellulases is optimum in an acidic to neutral pH range, we observed only slightly reduced ink removal at the ambient pH of the repulped stock, approximately pH 8.5.

Printing and writing grade paper requires a high level of brightness (80% to 85% on a scale of 100%) and less than 10 ppm residual ink (7). To meet these specifications, a dispersion unit is typically added at the end of the deinking process in European and some North American mills. In this process, residual ink particles are dispersed small enough to be washed or floated out of the pulp slurry or left in the pulp as invisible particles (8). Brightness is compromised if too much ink remains in the pulp. Pulp color is another parameter of special concern in recycled fiber. Some paper dyes are difficult to remove and contribute undesirable color to recycled fiber intended for printing and writing paper. Color stripping is best achieved by reductive bleach chemicals that alter pulp color as well as brightness. Sodium hydrosulfite or formamidine sulfinic acid (FAS) are frequently used in a bleach step added before, after, or in the disperger to meet brightness and color level targets.

Fiber Loading

Alkaline papermaking has made it possible to incorporate calcium carbonate into pulp. Because calcium carbonate is less expensive than fiber and has excellent optical properties, it is advantageous to add as much filler as possible. However, the benefit of increasing the amount of carbonate filler is offset by a corresponding decrease in inter-fiber bonding and ultimately a lower level of paper strength. When pulp is fiber loaded, more calcium carbonate can be incorporated into the fibers before bonding decreases. Figure 1 illustrates that for a comparable strength on paper made with bleached hardwood, approximately 4% more carbonate tiller can be incorporated by fiber loading than with the conventional direct addition method. Increased carbonate retention is an additional advantage of incorporating calcium carbonate within fiber lumens and cell walls. This attribute is especially important during recycling when greater retention translates into less sludge and lower suspended solids in the effluent load from recycling (Table 1).

Fiber loading is a two-step process. Calcium hydroxide is mixed into pulp (either virgin or recycled) fibers at a high consistency and subsequently is reacted with carbon dioxide in a pressurized refiner. The result is complete conversion of calcium hydroxide to calcium carbonate that can be confirmed by a stable pulp pH of approximately 8.5. If any calcium hydroxide remains, the pH of the pulp mixture is more than 10. Twenty to 30% of the calcium carbonate precipitated during fiber loading is deposited within pulp fibers. As more carbonate is precipitated in the pulp mixture, more calcium carbonate can be incorporated within the lumens and cell walls.

An unexpected advantage of the fiber-loading process is that mill stack gas can be used as the source of reactant carbon dioxide. Table 2 illustrates that complete conversion of calcium hydroxide occurred when the carbon dioxide reactant was mixed in various concentrations with nitrogen to simulate stack gas. Nitrogen and carbon dioxide were premixed in cylinders and added at both the top and bottom of the reaction chamber to ensure distribution through the pulp in the brief exposure time of 1 or 2 min under 3 to 6 bars pressure. A pressurized refiner was used for dispersing the pulp after reaction. The percentage of ash is a measure of carbonate remaining inside the fiber after vigorous washing.

The most important initial application of fiber loading may be in processing secondary fibers. Fiber loading has the potential to upgrade deinked pulp by increasing brightness, improving color, and masking residual ink and other contaminants (Table 3). Color is measured in values that indicate whiteness, red-green content, and yellow-blue content (9). As more papers entering the mixed office waste stream contain recycled fibers, this furnish will become even more problematic to deink

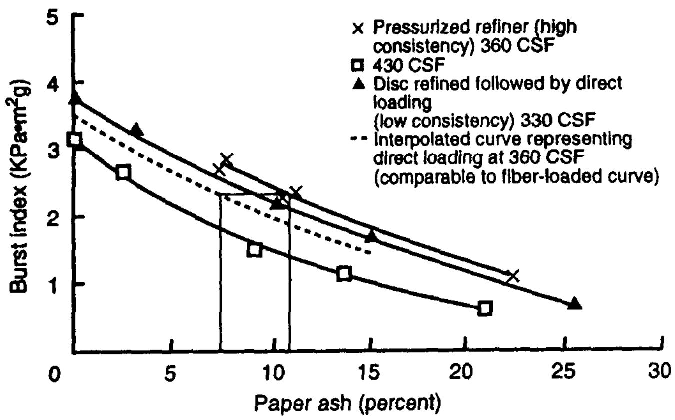

Fig. 1. Comparison between direct and fiber loading on bleached hardwood kraft pulp.

Table l-Ash retention during recycling of fiber-loaded pulp compared with conventional filler addition

	Ash retention (%)	
Specimen	Conventional	Fiber-loaded
Paper ash		
Initial	7.41	6.84
Recycled	2.28	5.08

Table 2—Percentage of calcium carbonate deposited within fibers using nitrogen:carbon dioxide gas mixture simulating mill stack gas (ambient temperature).

Sample	Reaction time (min)	Pressure (bars)	Carbon dioxide concentration (%)	pH	Ash (%)
1	1	3	18	8.7	2.11
2	2	3	18	8.5	3.03
3	2	3	32	8.5	3.03
4	2	6	18	8.3	2.46
5	2	6	32	8.6	2.74

and upgrade. Fiber loading could be the process that enables recycling of mixed office waste containing mechanical fibers by providing the alkaline reservoir necessary to stabilize these pulps (10). Because fiber loading can upgrade the dispersion step now used in deinking mills, deinked pulps that fall short of the printing and writing requirements for dirt count or color could be improved enough to be upgraded and subsequently incorporated with virgin fiber to make printing and writing paper.

Table 3—Effect of bleaching and fiber loading on brightness, color, and residual ink

	Content (%)				
	Brightness	Whiteness	Red-green	Yellow-blue	Residual ink (ppm)
Initial deinked Pulp	73	91	-0.1	5.7	180
After 1% sodium hydrosulfite bleach	82	95	-0.5	4.0	138
After fiber loading	86	96	-0.2	3.1	12

EXPERIMENTAL

Enzyme Deinking

Office waste paper collected at FPL was used as the paper furnish. This furnish was sorted to include approximately 80% laser and xerographic printed paper. The paper was shredded and mixed to ensure a homogeneous stock for trials.

A 5-L capacity Hobart mixer equipped with a mixing paddle was used for the laboratory-scale pulping at the low-speed agitation setting. The mixing bowl was jacketed to control temperature during pulping. A Voith high consistency pulper with a 50-L capacity was used for pilot scaleup trials.

For laboratory-scale trials, 250 g (ovendry basis) shredded paper was soaked overnight and fiberized at 16% consistency with 50°C soft tap water. Surfactant was added to the pulper on a 0.05% on ovendry pulp basis. At the end of a 15-min fiberization step, diluted enzyme preparation was applied at a 0.4 ml commercial concentrate/kg dry fiber basis, and pulping was continued for 20 min. The pulping stage was done at 14% consistency.

For the pilot-plant trials, identical procedures were followed, except that 8 kg (ovendry basis) shredded paper was added directly into the high consistency pulper without presoaking.

Pulped samples were floated at 1% consistency in 43°C tap water. An 8-L capacity laboratory Denver cell and 75-L pilot-scale Denver cell were used, Additional surfactant was not added to the flotation cells. Flotation accepts were dewatered on an 80-mesh screen.

Fiber Loading

Reagent grade calcium hydroxide was used for experimental fiber-loading work. Papermaker quality precipitated calcium carbonate was used for direct-loading experiments. Bleached kraft hardwood wet lap pulp was obtained commercially. Office waste paper was collected at the FPL and shredded or hammermilled prior to pulping.

A bench model Hobart mixer with a 76-L stainless steel bowl and flat beater was used in this study. A Sprout-Bauer 305-mm pressurized disc refiner was used as both the reaction chamber for precipitating calcium carbonate and the refiner for incorporating it into pulp fibers. Sprout-Bauer refiner plates, patterns C-2975-C and 2975-1C (Devil's teeth) were used in this study.

The following two-step fiber-loading procedure was followed:

1. Incorporation of calcium hydroxide: For each experimental run, 1-kg ovendry fiber was blended in a Hobart mixer with appropriate amount of calcium hydroxide and water required for the desired chemical load and consistency.

2. Precipitation of carbonate: High consistency (21%) pulp containing calcium hydroxide was loaded into the refiner feed tank. Carbon dioxide was injected into the feed tank to react with the calcium hydroxide in the pulp. Carbon dioxide was held in the tank long enough to attain 138 kPa pressure. During this interval (several minutes), calcium carbonate was precipitated in the pulp fibers. The pulp was then refined in a carbon dioxide atmosphere at the desired plate gap and feed rate to provide intimate contact of the carbonate and fibers.

To compare the two methods, an appropriate excess amount of reagent grade calcium carbonate was added directly into the doler tank during handsheet preparation to match the paper ash level of the fiber-loaded handsheets.

Pulp and Paper Tests

Handsheets (60 g/m^2) were prepared according to Tappi Test Method T 205. Ash content was assessed by Tappi Test Method T 211. Burst was measured according to Tappi Test Method T 403. Residual ink was measured on an image analyzer; particles counted were 0.02 to 0.20 mm^2. Brightness was measured following Tappi Test Method T 525.

CONCLUSIONS AND RECOMMENDATIONS

Two new processes— enzyme deinking and fiber loading-can be combined to upgrade mixed office waste.

Benefits of enzyme deinking include the following:
- Removes toner inks
- Improves effluent quality by using less chemicals
- Increases pulp drainage for papermaking
- Costs the same or less than chemical deinking
- Saves electrical energy during processing

Benefits of fiber loading include the following:
- Utilizes waste carbon dioxide from stack gases
- Extends fiber resource by substituting filler for fiber
- Retains filler during recycling which minimizes sludge
- Reduces observable residual ink and contaminants on recycled fiber
- Improves paper brightness and color

The future of recycling mixed office waste depends on creative and green technology capable of dealing with an ever-changing paper source. As additional recycled fiber is included in printing and writing paper, it is inevitable that more mechanical and unbleached fibers will enter the office waste stream. Increased recycled fiber content should be encouraged. Technology will have to adapt to this change in fiber content just as it has had to evolve to accommodate nonimpact inks. We will continue to address these changing needs, We plan to investigate fiber loading as the source of alkalinity required for mechanical pulp permanence.

LITERATURE CITED

1. Iannazzi, F., *Proceedings of Wastepaper IV Conference*, "Supply, Demand, and Future Prices for OWP," Miller Freeman Inc., Sect. 18(1993).

2. Badar, T., *Progress in Paper Recycling*, "Environmental Impact of Recycling in the Paper Industry," 2(3): 42 (1993).

3. Jeffries, T., Klungness, J., Sykes, M., and Cropsey, K., *Tappi Journal*, "Comparison of Enzyme-Enhanced With Conventional Deinking of Xerographic and Laser-Printed Paper," 77(4): 173 (1994).

4. Kim, T–J., Ow, S., and Eom, T–J., *Tappi 1991 Pulping Conference Proceedings*, "Enzymatic Deinking Method of Wastepaper," TAPPI PRESS, Atlanta, 1991, p.1023.

5. Klungness, J., Caulfield, D., Sachs, I., Tan, F., Sykes, M, and Shilts, R., *Tappi 1994 Recycling Symposium Proceedings*, "Fiber-Loading: A Progress Report," TAPPI PRESS, Atlanta, 1994, p.283.

6. Seldin, I., *Tappi 1994 Pulping Conference Proceedings*, TAPPI PRESS, Atlanta, 1985, p.303.

7. Thompson, C., *Recycled Papers: The Essential Guide*, The MIT Press, Cambridge, Mass., 1992, p.105.

8. Ferguson, L., *Tappi 1994 Pulping Conference Proceedings*, "Comparison of North American, European, and Pacific Rim Deinking Technologies,"TAPPI PRESS, Atlanta, 1994, p.869.

9. Sharpe, P.E. and Lowe, R.W., *Tappi 1993 Pulping Conference Proceedings*, "The Bleaching of Colored Recycled Fibers," TAPPI PRESS, Atlanta, 1993, p.1205.

10. Page, D., *Pulp and Paper Canada*, "Demand For Permanent Paper Comes From Many Sources," 95(2): 10(1994).