RECYCLING OLD TELEPHONE DIRECTORIES

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EXECUTIVE SUMMARY

Each year a substantial amount of old telephone directories (OTD) are available for collection and recycling. Processing OTD requires knowledge of their recyclability. This investigation intends to provide basic information to recycle OTD and to gain operational experience on a new generation of laboratory flotation cell-Delta25. It was found that OTD contains fibers that are equal to or better than ONP (old newsprint) in terms of mean fiber length and the amount of contaminant in the furnish. Deinking of OTD is similar to ONP, but requires higher water hardness due to higher ink concentration. The newly designed laboratory flotation cell shows good runnability and efficiency with the addition of an automatic foam skimmer. A brightness gain of 9.5 points was achieved with OTD. However, because of the yellow ink in OTD the maximum brightness achievable is only 46%. When incorporated in ONP/OMG (old magazines) furnish, brightness drops 1.4 points for each 10% increase of OTD. OTD does not respond to reductive bleaching, i.e., hydrosulfite and FAS bleaching. This is a result of the publisher's switch from dyed yellow pages to printed yellow pages.

ABSTRACT

There are about 750,000 tons of old telephone directories (OTD) available each year for collection and recycling. Processing OTD requires knowledge of their recyclability. This investigation intends to provide basic information on recycling OTD and to gain operational experience on a new generation laboratory flotation cell-Delta25. It was found that OTD contains excellent fibers that are equal to or better than ONP (old newsprint) in terms of mean fiber length and the amount of contaminant in the furnish. Deinking of OTD is similar to ONP, but requires higher water hardness due to higher ink concentration. The newly designed

laboratory flotation cell shows excellent runnability and efficiency with the addition of an automatic foam skimmer. A brightness gain of 9.5 points was achieved with OTD. However, because of the yellow ink in OTD the maximum brightness achievable is only 46%. When incorporated in ONP/OMG (old magazines) furnish, brightness drops 1.4 points for each 10% increase of OTD. OTD does not respond to reductive bleaching, i.e., hydrosulfite and FAS bleaching. This is a result of the publisher's switch from dyed yellow pages to printed yellow pages.

Application: Basic information of OTD is provided for future process designs to recycle OTD. The application of a new lab flotation cell provides a new tool for simulating performance of industrial flotation cells.

INTRODUCTION

Availability of Old Telephone Directories

The major advantages of using OTD as a fiber source are its consistent supply and uniform quality. Since it is very easy to recognize OTD, recovered OTD usually contains no prohibitive materials and low out-throws. Yellow Pages Publishers' Association (YPPA) has developed an advanced system to recover out-dated directories. Individual directory publishers have taken an active role in their collection which has led to the steady rise in OTD supply. The other reason for increased OTD supply is the booming economy. The advent of internet technology prompts rapid growth of small business, which in turn results in increased listings in the yellow pages (not white pages). Whereas the total delivery of telephone directories in 1994 was 294,415 tons *(1),* the tonnage of paper purchased by YPPA members reached 550,805 tons in 1996 and 600,341 tons in 1997 *(*2). According to YPPA, 6,000 directory titles were published in 1998 and total circulation reached 350 million copies (estimated at 750,000 tons). The actual number may be higher because of undistributed overrun copies.

The recovered OTD is being incorporated in a variety of products, such as boxboard, gypsum wallboard backing, animal bedding/composting, tissue wrapping paper, corrugating medium, chipboard, cellulose insulation, core board, asphalt shingles, roofing paper, hydro-seeding mulch and ceiling tiles. Others grades include directory paper, newsprint, and envelopes. In 1993, at least three mills incorporated OTD to produce either newsprint or directory paper *(3)*. Daishowa America Co. Ltd., Prot Angeles, WA used 10,800 tons, accounting for 15% of their furnish. Newstech Recycling Inc., Coquitlam, B.C. consumed 6,615 tons, approximately 4% of its total recycled paper. Bowater Inc., Calhoun, TN, also used an unknown amount of OTD.

OTD as a Recycled Paper Stock

Two critical issues have been hurting the increasing utilization of OTD. The first is printing ink. The ink used in directories is similar to daily newspapers. Directories are printed in a variety of methods just like newspapers, e.g., offset, letterpress, or flexography. However, the amount of ink printed on paper is fairly different between the two products. This difference arises from the basis weight of directory paper and newsprint. The basis weight for newsprint is usually 43-49 g/m^2. The basis weight for directories is lighter. For instance, the basis weight of directory paper grade produced at Daishowa America ranges between 29-42g/m^2 (18-26 lbs/3000 ft^2).

Assuming printing density (amount of printed ink per unit area) is the same for both grades, the amount of printed ink per unit weight of paper would be higher for the lower basis weight grade. For example, to compare the newsprint of 50.1 g/m^2 to the directory of 41.6 g/m^2, the directory contains (1/41.6-1/50.1)/(1/50.1)=20% more ink than the newsprint. Both soybean and petroleum oil based inks are used in directory printing. Directory publishers switch to soybean oil based ink to print color advertisement. It have been proven that aging will make these soybean oil based inks more difficult to detach from fiber surface and to remove by flotation *(4)*.

The second issue is the bleachability of yellow pages. Telephone directories contain white pages for residential and government telephone listings, and yellow pages for business and advertisement listings. The yellow color is achieved either by adding dyestuff in pulp at the time of production, or using color ink to tint white paper yellow on press. The latter is the trend in the industry since it provides more options to advertisers. Presently there is no proof that one type of yellow page is more suitable for recycling than the other in terms of color stripping. Both are difficult to process in a recycling plant.

Other issues which are of recycler's concern are whether binders in phone directories become stickies and whether cover pages need special treatment.

The new trend that influences the quality of OTD in the yellow pages publishing industry is source reduction *(5)*. It is accomplished by lowering basis weight, reducing page margins, and switching to downsized directory books. For instance, the National Office Paper Recycling Project has presented NYNEX with a National Leadership Environmental Responsibility Award for reducing the page margins that led to the saving of 750 tons of paper. All of these practices increase the amount of printing ink in directories, making them even more difficult to process.

Objectives

This project is set up to gain first-hand knowledge of OTD as a recycled paper furnish and provide basic information for process design. When processing OTD, we applied a newly designed laboratory flotation cell to study the OTD process conditions. We will discuss in detail the principle and runnability of this flotation cell.

EXPERIMENTAL

Repulping was carried out in a 0.05m^3 HD laboratory pulper, in which a helical rotor was installed. Each batch of repulping requires 5 kg recycled paper. Defibered stock was transferred to a laboratory flotation cell after being diluted to 1% consistency. The volume of the cell is 25 Liters. Details of the cell will be discussed later. Washing of pulp was performed in a decker with 150 mesh wire. Bleaching was performed in a Mark IV Quantum Reactor under controlled pH, temperature, time, and consistency. The measurement of pulp quality was performed according to following methods and instruments:

Properties	Method	Instrument
Mean fiber length and fines	Voith Procedure	Optest Fiber Quality Analyzer™
Brightness	ISO 2469	Technidyne Color Touch™
ERIC	TAPPI T567	Technidyne Color Touch™
Residual Ink	Voith Procedure	Optest Inkscanner™
Ash	TAPPI T211	Lindberg Muffler
Stickies	TAPPI T277	Optomax™ Image Analyzer
Debris	TAPPI T278	Valley™ Screen with 0.004" Slot

RESULTS AND DISCUSSION

Composition of OTD

Three types of OTD were collected and analyzed. The first was the Fox Cities (WI) area 1997-1998 directory published by Ameritech. The second was the Fox Cities area 1997-1998 directory published by McLeodUSA. The third was the Denver (CO) area 1998 overrun directory also published by McLeodUSA. These OTD were ripped apart and then sorted into white pages, yellow pages, covers, inserts, and binders. **Table I** gives the weight percentage of each component. **Table II** gives ash and fiber quality data of each component. Data were also collected from a local newspaper-Post Crescent (Appleton, WI) for comparison.

Publisher	Cover	Inserts	White Pages	Yellow Pages	Binder[b]
Ameritech	2.2	1.7	43.5	49.8	2.8
McLeodUSA I	2.1	0.9	51.0	44.3	1.7
McLeodUSA II	1.3	0.0[a]	39.2	57.5	2.0

[a] There are no inserts in McLeodUSA II.

[b] Peeled binder still contains a significant amount of fiber. The sample was extracted with trichloroethane and the average weight percentage of extractives is 32.28%.

Table I. Weight percentage of individual components in OTD.

In general, text pages account for 95% of total phone directory weight, of which 50% is yellow pages and 45% is white pages. The rest 5% of the furnish is cover page, inserts, and binder. Binder is the only non-fiber component. Two types of adhesives are currently used for binding directories. The most commonly used is animal glue that is water-soluble. It could also be conventional hot-melt adhesives that become sticky hazard in process. We found out that McLeodUSA I applied hot melt adhesives, while McLeodUSA II and Ameritech applied water-soluble glue. The amount of hot melt adhesives in McLeodUSA I is approximately 0.9% of total directory weight. Due to low non-fiber contaminants, recycling yield from OTD is expected to be high.

OTD Components	Lw-Mean Fiber Length (mm)[a]	Lw-Fines Content (<0.2mm), %[a]	Ash (525°C) (%)
Ameritech			
Cover	0.97	33.46	17.50
Inserts	1.26	14.66	22.69
White Pages	1.18	8.39	3.71
Yellow Pages	1.20	13.56	3.56
McLeodUSA I			
Cover	1.03	9.17	12.62
Inserts	0.95	11.97	21.19
White Pages	1.46	11.62	5.47
Yellow Pages	1.62	8.60	0.77
McLeodUSA II			
Cover	1.32	9.39	14.56
White Pages	1.31	19.53	1.79
Yellow Pages	1.44	16.19	2.33
Post-Crescent ONP	1.31	12.36	1.16

[a] Length weighted average fiber length

Table II. Ash and fiber analysis of OTD components.

Fiber quality analysis showed that OTD contains better or equivalent fiber in comparison to ONP. Two of the three furnishes studied have higher mean fiber length with similar amount of fines content. Directory paper is a specialty lightweight uncoated paper. The majority of pulp furnish is TMP or RMP. While newsprint is generally made from mechanical fiber, directory paper furnish contains a substantial amount of chemical pulp for strength enhancement. The cover page is made from bleached chemical pulp.

In addition to the above differences, OTD contains a higher amount of ash than ONP. While ONP contains only 1.2% ash, white and yellow pages contain an average 2.8% ash, which is from the added filler for opacity of directory paper. Cover and inserts, which are usually coated, contain 13 to 23% ash. This part of ash increases the total ash to 3.8% by weight of directory.

The brightness and color of blank white and yellow pages are presented in **Table III**. The white page resembles newsprint with similar a^* and b^* value but with lower brightness. The yellow page contrasts with the white page with its yellow tint. The yellow color value (positive b^*) is extremely high, ranging between 25 and 30, while the green color value (negative a^*) is lower than the white page. The brightness is about 20 points lower than the white page at 30-32%. The yellow tint presents a major challenge to recycling plants. That led to Mr. Rex Springer of Daishowa's comment *(6)* that the mill's ability to consume OTD depends on its ability to handle the "yellow contamination."

OTD		ISO Brightness, %	L^*	a^*	b^*
Ameritech	*White*	52.05	81.50	-0.45	7.91
	Yellow	32.10	77.81	-4.63	24.65
McLeod I	*White*	55.59	84.03	-0.06	8.50
	Yellow	30.41	79.68	-5.77	30.27
McLeod II	*White*	50.19	80.26	-1.17	7.52
	Yellow	31.87	79.52	-4.28	27.87

Table III. Brightness and color of un-printed white and yellow pages (tested on blank edges).

Repulpability

The furnish selected for repulpability and subsequent studies was McLeodUSA II. Debris content, which is a measurement of defibering extent, was tested at different pulping times to establish a defibering curve. Two pulping series were performed: neutral and alkaline. In neutral pulping no chemicals were added (pH 6), and in alkaline pulping peroxide and silicate were added at typical dosages (1% peroxide, 0.5% silicate, pH 9.6). In order to study the impact of cover and binder, the OTD was repulped in three steps. The first pulping was with text only (white and yellow pages). The second pulping was with text and cover but without binder. The last pulping was with a whole phone book. The defibering curves are plotted in **Figure 1**.

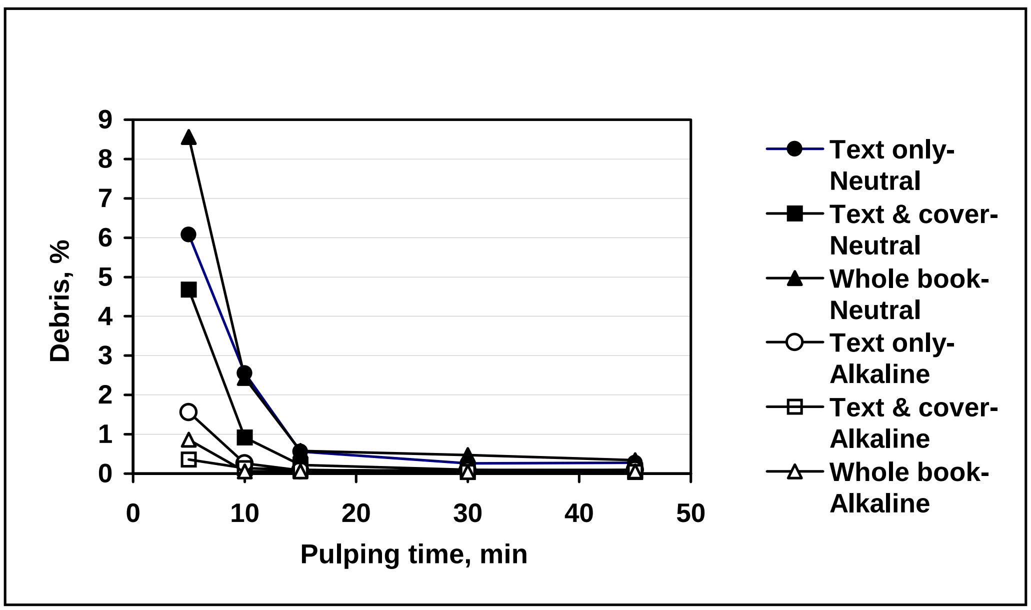

Figure 1. Defibering curves with different OTD composition (11% Cs, 43ºC).

OTD was readily repulped, even with the binder spine in it. Defibering of OTD is similar to ONP. Ten minutes repulping under a neutral condition or five minutes under an alkaline condition were sufficient to carry defibering to completion. The considerable difference between neutral and alkaline repulping is likely caused by fiber swelling. Cover and inserts were found to lower the residual flake content in the repulped stock. This is because cover and inserts contain high ash, which facilitates the circulation of stock. The relative long pulping in neutral condition could increase ink fragmentation, and potentially re-deposition to fibers.

Most directories use a varnish over the printed cover to protect it. We found the varnish cover pages can be repulped completely. Tests indicated ink on cover page is neither UV-cured nor laminated plastics. Inspection of debris at different repulping times showed it is readily broken down. Most directories nowadays use an aqueous based coating which is not an issue in recycling plants. Solvent based, laminated, plastic or UV coatings lower the recyclability of directories and the YPPA technical guidelines suggest avoiding such coatings on covers, inserts, tabs or special sections.

When the binder was added to the furnish, debris did not increase with alkaline pulping. The debris content did increase when neutral pulping was applied. With a 10 min pulping time the debris content increased from 0.9 to 2.4 %. This shows that the binder is more soluble in an alkaline environment than in a neutral environment. Either way, animal glue will eventually be dissolved in the process and does not pose a sticky problem. The hot-melt adhesive binder is not broken down in short pulping time, thus most of it can be removed by coarse screening.

Flotation and Bleaching

Flotation was carried out in a laboratory flotation cell (see **Figure 2**). The operating principle of the machine lies on the rotating air injector at the bottom of the cell. The rotating motion of the rotor induces negative pressure turbulence on the outside of the blades that draw in ambient air through a hollow shaft. The rotor also causes the suspension to blend with the air. The amount of air taken in is measured with an air flow meter and is adjustable. An automatic skimming pad conveys foam through a central foam funnel into the foam outlet (see **Figure 3**). The liquid loss caused by the foam overflow is compensated for by adding fresh water or processed water. Fresh water or processed water is also used to make up for any losses in fiber stock suspension removed to perform a series of tests. **Figure 4** shows the foam collected from OTD flotation.

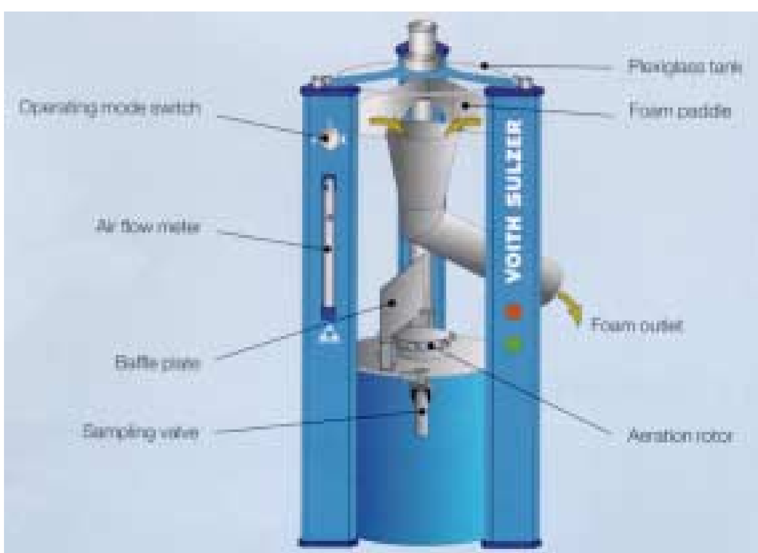

Figure 2. The laboratory flotation cell setup.

Figure 3. The automatic foam skimmer on top of the flotation cell.

Figure 4. Foam collected during OTD flotation.

After repulping, five flotation trials were run. Flotation conditions were recorded in **Table IV** and the results are listed in **Tables V** and **VI**. Flotation accept from Run 2 was used for the hydrosulfite bleaching experiment. Accept from Run 3 was used for the FAS bleaching experiment. In runs 4 and 5 we replaced part of ONP with OTD. Test results from Run 4 and Run 5 will be discussed in next section.

Run No.	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Furnish	100% OTD	100% OTD	100% OTD	20% OTD 50% ONP 30% OMG	50% OTD 20% ONP 30% OMG
Consistency, %	1.0	1.0	1.0	1.0	1.0
Temperature, °C	47	52	48	51	52
Air Intake, L/min	5-7	5-7	5-7	5-7	5-7
Water Hardness, ppm	170	204	250	250	250
Time, min	15	15	15	15	15
Reject Rate, %	5.6	10.2	18.0	--	--

[a] Pulping condition: Runs 1, 2, and 3: 1.0% H_2O_2, 1.0% Silicate (30% conc.), 0.6% MT 90, initial pH 10.5, final pH 9.5, 10-11%Cs, 10 min, and 51-55 °C. Runs 4 and 5: 1.0% H_2O_2, 2% Silicate, 0.4% MT 90, Initial pH 9.8, Final pH 9.3, 10-11% Cs, 10 min, and 52-54 °C.

Table IV. Flotation condition[a].

Sample ID		**Feed**	**Run 1 Accept**	**Run 2 Accept**	**Run 3 Accept**	**Wash[a] Accept**
ISO Brightness, %		36.13	41.25	43.81	45.64	46.37
L^*		71.55	75.76	77.61	78.52	79.19
a^*		-1.81	-1.44	-1.35	-1.38	-1.54
b^*		8.68	9.60	9.81	9.35	9.71
Residual Ink (10-80 µm)						
Ppm		7950	4530	2810	3850	3360
ERIC, ppm	*Felt*	970.6	611.9	545.4	568.0	563.4
	Wire	1162.2	730.4	610.2	587.7	587.2
Efficiency by ERIC %[b]		--	38.1	66.2	89.7	--

[a] Run 3 accepts were hyper-washed. Wash yield was 90%.

[b] Efficiency here and in Table VI are calculated according to the equation suggested by G. M. Dorris *(7)*.

$$E_f = 1 - \frac{(C_{acc}^{bot} - C_{acc}^{top})}{(C_{fd}^{bot} - C_{fd}^{top})}$$

Table V. Flotation deinking.

Sample ID		**Hydrosulfite Bleaching[a]**		**FAS Bleaching[b]**		
		Feed	**Acc**	**Feed**	**1% FAS**	**2% FAS**
ISO Brightness, %		43.81	42.66	45.64	42.55	42.82
*L**		77.61	76.28	78.52	77.00	77.59
*a**		-1.35	-2.43	-1.38	-1.94	-2.06
*b**		9.81	8.76	9.35	10.31	11.05
Residual Ink, ppm		2810	1320	3850	1300	1570
ERIC, ppm	*Felt*	545.4	775.8	568.0	637.5	633.5
	Wire	610.2	798.8	587.7	641.7	645.0

[a] Y-bleaching condition: 1.0% sodium hydrosulfite, 12% consistency, 45 min, 60 °C, initial pH 6.6, final pH 6.9.

[b] FAS bleaching condition: 15% consistency, 81-87 °C, Initial pH10, Final pH 7, 30 min.

Table VI. Test results of FAS and Hydrosulfite bleaching after flotation.

The laboratory flotation cell has shown good runnability and efficiency. The self-aspirated air injector smoothly introduces air at the bottom of the container, creating fine bubbles in the stock. Foam and stock travel in a helical mode, extending the distance before reaching the surface of the stock. The relatively long travel distance gives foam better opportunity to agglomerate with each other, allowing them to be readily removed by a foam skimmer. In the past the design of laboratory flotation cells required manual skimming. So, the reject rate depended largely on the frequency and amount of skimming. The automatic foam skimmer installed on the new flotation cell continuously removed foam generated during flotation. This change has improved the reproducibility of the test results.

The trial results showed that black ink particles printed on OTD were readily removed by the flotation process with traditional fatty acid soap. Rejects from flotation were highly concentrated and have a very oily appearance. Further washing after flotation did not lower ERIC number, indicating all free ink was removed by flotation.

The maximum brightness gain reached 9.5 points after flotation with 90% ink removal efficiency. The brightness of flotation accept is 45.6. At this brightness level, it will be difficult for any paper mill to use 100% OTD. This low pulp brightness appears to be related to yellow tint in OTD. Tests on unprinted yellow pages indicate they have an abnormally high ERIC at 462 ppm, indicting the yellow pigments have a high light absorption coefficient. Since the yellow color value (positive b^*) has no substantial change through flotation and washing, the adsorbed yellow pigments appeared to be unremovable by flotation or the washing process.

The optimum water hardness for OTD flotation was higher than that required for traditional ONP. When increasing water hardness from 170 to 250 ppm, the brightness gain was increased by 4.4 points (see **Figure 5**), and ink removal efficiency was increased from 38% to 90%. Since the ink concentration in OTD is 20% higher than that in ONP, collection of detached ink particles would require more calcium ions.

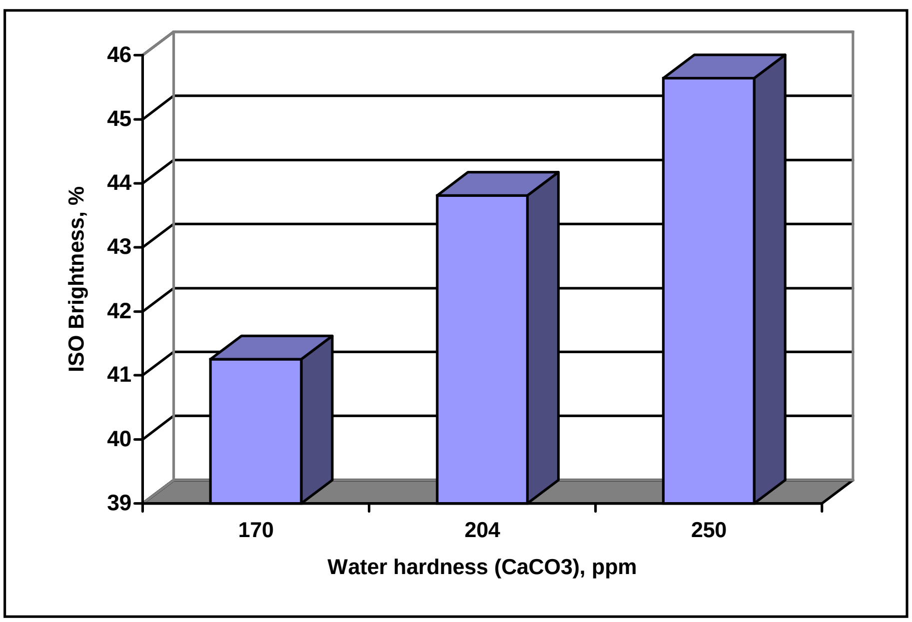

Figure 5. Influence of water hardness on brightness of treated OTD.

There was no brightness gain of OTD after reductive bleaching, i.e., hydrosulfite and FAS bleaching. The brightness after FAS bleaching decreased significantly due to alkaline yellowing effect. In hydrosulfite bleaching, the yellowness value, b^* , dropped only slightly, and it increased somewhat after FAS bleaching. The b^* value stayed at 9-11 throughout the treatment of OTD, in comparison to 6-7 for typical ONP and 7.5-8.5 for unprinted white pages. It appears that the yellow color in OTD cannot be stripped with current bleaching chemicals.

Though there are successful reports *(8, 9)* that yellow tint in OTD may be stripped with hydrosulfite or FAS, the color material used for creating yellowness has been changing since then. According to the YPPA 1996 environmental council action plan *(5),* publishers have been switching from dyed yellow pages to printed yellow pages throughout the industry. It is likely that pigments are used in yellow tint. These pigments may well be the reason why reductive bleaching chemicals are not effective anymore. However, without knowing the chemical nature of current yellow tint material. The statement here is only inconclusive.

Comparison between OTD and ONP

The following work compares the optical and strength properties of pulps with different ratio of ONP, OTD, and OMG (**Tables VII** and **VIII**). The purpose is to determine the achievable quality when incorporating a certain amount of OTD to replace ONP. Test results indicate that brightness decreases linearly with the increasing amount of OTD when OMG is fixed at 30%. For each 10% increase of OTD, there is a drop of 1.4-brightness points (**Figure 6**). The yellowness in final pulp gradually increases with OTD.

Furnish		**70% ONP 30% OMG**	**20% OTD 50% ONP 30% OMG**	**50% OTD 20% ONP 30% OMG**	**100% OTD**
ISO Brightness, %		59.81	57.54	51.78	45.64
L^*		84.96	84.61	81.88	78.52
a^*		-1.92	-0.85	-1.65	-1.38
b^*		6.05	7.50	8.51	9.35
Residual Ink (10-80 μm) ppm		3030	2420	4390	3850
ERIC, ppm	*Felt*	230.5	318.1	380.0	568.0
	Wire	237.4	337.0	422.7	587.7

Table VII. Comparison of brightness and residual ink in pulps with different percentage of OTD.

Furnish	**Stickies (T 277) mm^2/kg**	**Bulk (cm^3/g)**	**Tensile Index (N.m/g)**	**Burst Index ($kPa.m^2/g$)**	**Tear Index ($mN.m^2/g$)**
70% ONP 30% OMG	735	2.30	35.65	1.875	7.74
100% OTD	394	2.73	28.70	1.292	7.33

Table VIII. Comparison of strength properties and stickies content.

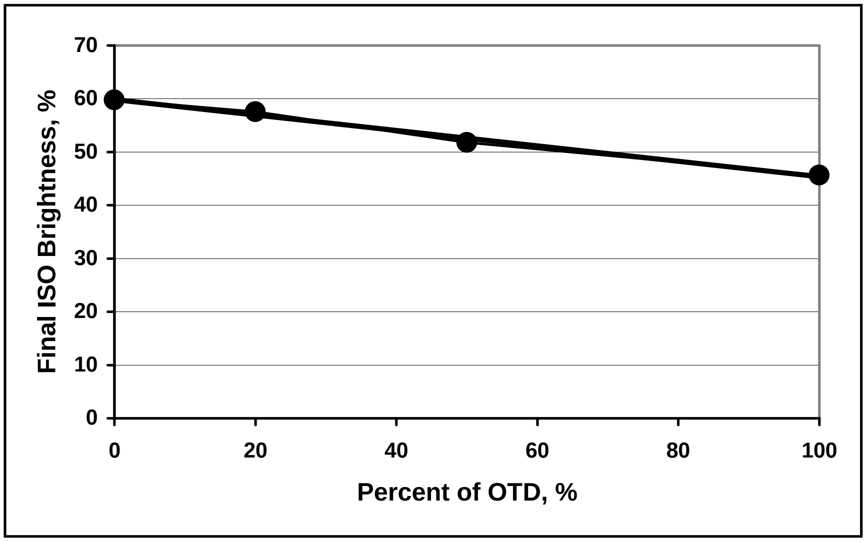

Figure 6. Brightness of pulp at different levels of OTD.

The strength properties of 100% OTD are inferior to 70% ONP/30% OMG. Both tensile and burst strength of OTD are lower than that of 70% ONP/30% OMG, in spite of the fact that OTD has longer mean fiber length. OTD pulp has poorer comformability, which is indicated by its high bulk. Stickies content in OTD, tested according to TAPPI T 277, is lower than typical 70% ONP/30% OMG. Since stickies of an OTD sample were measured immediately following repulping, the low stickies content indicates that binders in the directory books do not cause sticky problem.

SUMMARY

Based on this informational study of old telephone directories, the following points should be considered when designing future processes for recycling OTD.

a) Old Telephone Directories have been generated in record speed the last few years. These directories contain excellent fibers that are equal to or better than ONP in terms of mean fiber length and level of contaminants in stock.

b) Repulpability of OTD is good. Cover and insert pages, containing 13 to 22% ash, facilitate the pulp circulation during pulping. UV-cured ink or plastic laminated cover are not common in OTD nowadays. When binders used in directory books are animal glue, they are dissolved in water and do not pose a sticky problem.

c) Inks applied to directory books are similar to ONP, and deinking of OTD is also similar to ONP. OTD contain about 20% higher ink concentration than ONP. Therefore, it requires higher water hardness to achieve high deinking efficiency.

d)The new laboratory floatation cell has shown good runnability and efficiency. A brightness gain of 10 points was achieved with the cell. Continuous foam skimming improves reproducibility of test results.

e) The highest brightness achieved with OTD is about ISO 46%. Further washing does not increase brightness. When incorporated in ONP/OMG, brightness drops 1.4 points for each 10% increase of OTD.

f) OTD does not respond to reductive bleaching, i.e., hydrosulfite and FAS bleaching. Yellow tint, indicated by b* value, remains high after bleaching. This is a result of recent switch from dyed yellow pages to printed yellow pages.

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