4-1979

The Deinking and Bleaching of Pulp Produced from Household Wastes

R. Bruce Nelson
Western Michigan University

THE DEINKING AND BLEACHING OF PULP PRODUCED FROM HOUSEHOLD WASTES

by

R. Bruce Nelson

A Thesis submitted
in partial fulfillment of
the course requirements for
The Bachelor of Science Degree

Western Michigan University
Kalamazoo, Michigan
April, 1979

Abstract

One of the problems that Americans have had to continually deal with is what to do with household and municipal wastes. The National Center for Resource Recovery in New Orleans has partially solved this problem by recycling usable materials from the garbage. At the present time, they are recycling iron, glass, aluminum, and other non-ferrous metals. They are also separating out approximately 350 tons per day of paper fiber. This study was designed to try and clean up that fiber, so that it could be sold as usable fiber.

A "garbage" pulp was synthesized in the recycling plant at Western Michigan University. It was run through screens and cleaners before being deinked. The final pulp was then bleached using four different bleaching sequences.

The most interesting results of this work came in the cooking stage. All forms of plastic attracted and retained ink particles. Because of this, the final unbleached pulp was very clean and had a brightness of 43.7. The best bleaching process was a 1.2%-1.2% peroxide-hydrosulfite type. This gave a final brightness of 54.5.

The pulp was deinked using two different methods. These were sidehill washing and flotation cell deinking. A Clark classification showed that the amount of fines in the flotation cell stock was much higher than the amount in the sidehill stock. This led to large differences in strength tests.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
BACKGROUND	3
EXPERIMENTAL PROCEDURE	13
RESULTS	18
DISCUSSION OF RESULTS	22
CONCLUSIONS	27
RECOMMENDATIONS	28
REFERENCES	29
APPENDIX	31

Introduction

Over the last ten years, American cities have been hit with an ever increasing problem. They don't know what to do with their solid wastes. The city of New Orleans has found a way to not only alleviate this problem, but make money out of it also. The National Center for Resource Recovery (NCRR) is operating a plant that takes household wastes and separates any material that may be reused.

This plant first takes the garbage from compacter trucks and runs it through a hammermill. A magnetic device separates the steel from everything else. Another machine uses an electric field to separate the aluminum. A device much like a gold miner's sluice box is used to separate the glass from the remaining wastes. Paper fiber is separated by the use of screens and cleaners.

At the present time, this mill is making its profit from the sales of recovered aluminum, steel, and glass. The paper fiber is being landfilled at a rate of approximately 350 tons per day.

During the summer of 1978, the NCRR came to Western Michigan University's Fiber Recycling Plant to see if the fiber produced could be cleaned up to a point where it could be sold for a profit. After the fiber was run through a series of screens and cleaners, it was made into paper on the Fourdrinier machine in the pilot plant.

This thesis was originally designed to find the best way of bleaching this fiber to a point where it could be used as a filler for low grade publication paper (65-70). At first, the NCRR was very interested in this idea, but when they found out how much

paper would be needed for a bleaching study (5 lbs.), they decided not to go along with the plan, due to a shortage of this paper.

After deliberating on this fact, it was decided that a pulp similar to that of the NCRR would be synthesized in the pilot plant. By hand picking ingredients from household wastes, a reasonable fascimile of the NCRR pulp could be produced. After this pulp was made up, it was run through cleaners and screens in the recycling plant. This pulp was then split up, with half being washed on the sidehill screens, and the other half being washed in the flotation cell. A bleach study was then done on these two pulps.

Background

A list of the ingredients that will be used to synthesize the NCRR pulp is shown in Figure 1. This list was chosen to include a general ratio of typical household wastes. No cans or bottles are included here because they are all easily removed at the NCRR by various machinery. Aluminum foil has been included here due to the possibility of a small amount passing through the aluminum separator.

The percentages used in the pulp make-up were choosen with the help of two books on solid-waste,[1,2] and conferences with Mr. Lyman Aldrich.[3] The exact makeup of the pulp is not really too important. This is due to the fact that one of the main characteristics of household waste is that it is always changing in content.

There are two general discrepancies in figure 1 from most municipal waste tables. The news value seems high and the corrugated value seems a bit low. The reason for this is that most tables include waste from grocery and department stores, which contribute almost all corrugated. Because this study was meant to work with household wastes, the corrugated fraction was decreased. After discussions with Mr. Aldrich, it was decided that the news fraction should be increased, mainly due to the fact that many communities have newspaper recycling centers. This study deals with the idea that newspapers are included in the solid waste, rather than being sorted out.

The first step in processing this pulp is to mix it up and cook it in the hydropulper. The variables that must be controlled here are temperature, cooking time and chemicals.

Figure I

Percentages	Pulp Make-up		
50	75	#	News
13.3	20	#	Corrugated
10	15	#	Coated magazine (50/50-low/high quality)
8.7	13	#	Food wastes
5.3	8	#	Office wastes (including carbon)
4.0	6	#	Paper bags
3.3	5	#	Boxboard
1.0	1.5	#	Leaves and grass
1.0	1.5	#	Grease and oil
.7	1	#	Plastic
.7	1	#	Dirt and sand
.3	.5	#	Aluminum foil
.3	.5	#	Styrofoam
1.3	2	#	Misc. (tree bark, manure, etc.)

For high groundwood papers such as this, the best temperature seems to be 140°-160° F. The cooking time is approximately 30-45 minutes, depending on how well the ink disperses. The consistency is typically 3-6 percent.

TAPPI Monograph number 31 gives a list of many chemicals that can be used in the pulper. Sodium peroxide is used in mixtures like this for two reasons. First, it is chemically active in converting glue, starch, and certain oils into water-soluble compounds. It also improves the brightness of pulps, as opposed to the noticeable darkening which occurs when groundwood is cooked in an alkaline solution without peroxide. Sodium silicate is commonly used to reduce discoloration of groundwood and to promote better cleanliness of the product. It also is used with sodium peroxide as a penetrant and dispersant, and in addition buffers the solution to a pH range favorable to the action of the peroxides. Many times a wetting agent such as Kreelon or Triton X-100 is used to speed up the soaking and pulping process.[4,5]

The pulping stage is quite important to the entire experiment. It is in the hydropulper that the ink particles are hopefully separated from the fibers. There has been at least one study done on the use of plastics to deink waste paper.[6] In the study cited, different plastics were added in the pulper to help the deinking process. According to the author, the hydrophopic nature of the plastics and the inks make them attract each other. The ink is deposited on the plastic and both are removed later in the process by screens. In a similar study by H. Mamers and D. Menz[7], polyethylene laminated milk carton board and bitumenized sacks were pulped up

together. The bitumen was deposited on the plastic and removed together. A mass balance showed that approximately 95 percent of the bitumen was removed. Almost 100 percent of the plastic was removed in later screening stages.

The removal of much of the unwanted materials from a pulp such as this is achieved through the use of many screens and cleaners. Screens will separate the good fiber from larger pieces of unwanted material according to size. Cleaners separate the two according to density. Material that is both lighter and heavier than the paper fiber is easily removed in these devices.

There are two main types of deinking devices used today to wash the dispersed ink out of the fiber. The older style is the sidehill screen. As the fiber passes over this screen, the water and dispersed ink are washed through the screen and into a sewer. The clean fiber leaves the screen and falls into a stock chest. This device used large amounts of water, but many people believe that is the best way to deink high groundwood paper.

The newer washing device is the flotation cell. This device takes the low consistency pulp and bubbles air through it. By using a soap in this process, a foam is formed on top. As the air bubbles pass through the pulp, they attach themselves to the dispersed ink particles. The ink particles are carried to the top and held in the foam. The dirty foam is then scraped off the top of the slurry. Thistype of device is very ecology minded. It uses roughly one-sixth of the water and produces about one-half of the BOD of a similar sidehill washer.[8]

Once the pulp has been cleaned and de-inked, there are many different ways to bleach it. Everybody has their own different

ideas on how to bleach a pulp of this type. The general consensus however, was that chlorine dioxide, chlorination, and hypochlorite should not be used.

According to TAPPI Monograph #27, chlorine dioxide produces an orange color with groundwood and other high lignin pulps that can only be discharged by consuming a very large amount of oxidizing agent. Since this bleach dissolves a very high amount of lignin, the yield is drastically lowered. Due to the very low yields and high chemical consumption, chlorine dioxide cannot be used economically for bleaching the type of pulp that is produced from household wastes.

The chlorination type of bleach is intended to delignify, rather than simply to decolorize pulp. This is similar to the chlorine dioxide stage. Although the chlorine is cheaper than chlorine dioxide, it still isn't a good bleach to use, due to it's low yields and possible degradation of cellulose.[9]

The hypochlorite bleach stage will delignify pulp, but it can also brighten it. If this bleach is used in large enough doses, it will not only delignify, but it will attack the cellulose as well, and produce a very weak pulp. Virginia Chemicals has suggested a method by which hypochlorite is used to remove some of the lignin and do small amounts of bleaching. Hydrosulfite is used as a second stage bleach to clean up the pulp and further bleach it.[10,11]

Hydrogen peroxide bleaching was recommended by Harold Partridge of Hooker Industries and Dale Hedquist of Blandin Paper Company. This bleach has more or less been accepted as the prime method for producing bleached mechanical pulps with high cleanliness, brightness

and brightness stability. Since the pulp being bleached will contain a high percentage of groundwood, peroxide should be a very good bleach.[12,13]

The normal concentration of H_2O_2 used (100%), based on bone dry pulp, is .5 to 1.5%. Above 1.5%, adding more bleach will increase brightness very slowly, Below .5%, not much bleaching is being done on the pulp.[9]

Other factors that affect peroxide bleaching include: consistency, temperature, total alkalinity of the liquor and pH.

As the consistency of the stock is increased, the bleaching time is reduced and brightness gain is increased. The optimum consistency is around 12 percent. At this consistency, the bleaching time is about 1.5 hours.

As the temperature of the pulp is increased, bleaching time is decreased. It has been suggested that the ideal temperature for this pulp is 160° F.

The total alkalinity is the amount of NaOH present based on the bone-dry weight of the pulp. The range of this should be 1.2-1.9%. At the higher consistencies and temperatures that will be used, an alkalinity of 1.4 should be best. This must be calculated when determining the chemical make-up of the liquor. If the alkali content is too high, the peroxide is not sufficiently stable during the bleaching period to produce the best results. Conversely, if the alkali is too low, the pulp does not receive the maximum benefits. 5.0% sodium silicate furnishes an additional .6% of alkali.[9]

Under average conditions, the initial pH of the pulp will be

10.5 to 10.8, dropping gradually to the 9.2 to 9.6 range at the end of the reaction time.

After the bleaching has been done, the pulp must be neutralized with a reducing agent. Sulfer dioxide is usually used, because it not only removes residual alkali and destroys residual peroxide. it also reduces any highly colored ferric ions to ferrous ions that are relatively colorless. In actuality then, the SO_2 is doing some bleaching by itself. The final pH after the addition of SO_2 is, usually about 7.

The peroxide bleach liquor contains the following four chemicals: magnesium sulfate (epsom salt), sodium silicate, hydrogen peroxide and sodium hydroxide. The magnesium silfate inhibits the breakdown of peroxide by traces of such metals as iron, copper, and manganese. The sodium silicate buffers the bleach solution and has a stabilizing effect on the peroxide. The hydrogen peroxide is acidic, and therefore, sodium hydroxide is added to provide the alkalinity required. Typical concentrations of these chemicals are:

	% on pulp	#/ton on O.D. pulp
Epsom Salt	.05	1
Sodium Silicate	5.0	100
H_2O_2	1.2	24
NaOH	1.4	28
Water -250 gallons		

The order of chemical addition to the bleach liquor is quite important. The epsom salt should be first added to the water, then the silicate, the caustic, and finally the hydrogen peroxide.

Failure to do this may result in the unwanted precipitation of some chemicals.

A common two-stage bleaching sequence for mechanical pulps consists of a peroxide bleach followed by a hydrosulfite bleach. The peroxide is conducted in the same manner as before.

The controllable variables that affect hydrosulfite bleaching are: consistency, temperature, pH, and chemical concentration.

Consistency is best at lower values with this type of bleaching due to the better mixing and less air introduced into the stock. Air decomposes hydrosulfites at a high rate. The optimum consistency for this type of bleach is around 3%. A chelating agent (sodium tripolyphosphate) is commonly used in hydrosulfite bleaching (.5%). This chemical helps stabilize the hydrosulfite so that less is needed.

With each increase of 20° F of the bleaching temperature, the final brightness increases about 1 point. Temperature also affects bleaching time. The optimum temperature seems to be about 160° F. Bleaching here only takes about 3/4 of an hour.

The best operating range of pH is 5.0-6.5. At a higher pH, there may be a yellowing of the stock and a pH below 4.5 will promote the decomposition of the hydrosulfite.

As the percent of hydrosulfite is increased to 1%, substantial brightness gains are made in a single stage bleach. Very little increase is noted above this concentration. As a second stage, the usual concentration of hydrosulfites is a little lower. Zinc hydrosulfite is preferred over sodium hydrosulfite due to its better stability.

After the pulp has been bleached, it must be washed to remove any hydrosulfite degraded products that may be in the solution.

A very simple bleaching process, suggested by Virginia Chemicals, consists of a single stage hydrosulfite bleach. The percentages of hydrosulfite are usually slightly higher than used in a two-stage process, but everything else usually remains the same.[5]

Another bleaching sequence suggested by Virginia Chemicals is a hypochlorite-hydrosulfite process. The hypochlorite is used first in small quantities to slightly delignify the pulp. After this, the hydrosulfite stage is used to decolorize the pulp. By using these bleaches in this order, the hydrosulfite should remove any yellowness left in the pulp by the hypochlorite.[10]

The controlling factors in the hypochlorite state are consistency, temperature, pH, and percent chlorine.

The consistency does not seem to affect the final brightness, but as the consistency increases, so does the rate of reaction. However, at consistencies over 10%, the rate of reaction is so rapid, it is hard to control. Virginia Chemicals recommends a consistency in the 8% range.

Temperature affects the reaction rate and final brightness. Too low of a temperature slows the reaction down so that adequate bleaching is not achieved in the time allowed. If the temperature is too high, bleaching will be too fast and will be difficult to control. High temperature will also cause hypochlorous acid to give up oxygen more readily, thus reducing the bleaching efficiency by converting part of the hypochlorite to chlorate. Virginia Chemicals feels that 110° F is the approximate temperature that should be used.

Best results are obtained with a pH of 9.5-10.5. Below 9, the pulp discolors and additional chlorine is needed to bring up the brightness. If the pH rises above 11, the pulp also discolors and requires additional chlorine.

Levels of Cl_2 suggested for a bleach of this type lie between .5 and 4%. Normal hypochlorite addition rates may reach 15%, but the bleach used here is removing only part of the lignin, not all of it. Removing all of the lignin would leave a bright, but very weak pulp.

After the pulp is treated with hypochlorite, it is neutralized to a pH of 5.0-6.0. This will remove any residual chlorine and prepare the pulp for bleaching with hydrosulfite.

Experimental Procedure

This study is made up of two sections. The first part is actually a deinking study. It was done in the Recycling Center of the Paper Department at Western Michigan University. This part had to be done well, because the second part, which was the bleaching, would not give good results if the ink had not be removed.

The first step in the deinking stage was to pulp up the assorted wastes in the hydropulper. The pulper used was a six foot diameter Black-Clawson with 5/8 " exit holes in the bottom. The cooking was done for 40 minutes at 140° F and 4% consistency. Chemicals added include: 3% sodium silicate, 2% sodium peroxide, and .3% triton X-100 (surfacant).

From the hydropulper, the stock was pumped to a Bird-Johnsson, model 8, vibrating screen with 1/8 " holes. Dilution water was added to keep the consistency around 1% so that the screen would work properly. This coarse screen removes the larger material from the pulp. A Bird Selectifier screen followed the Johnsson to remove smaller sized unwanted material. This screen has .018" slots and was also run at 1% consistency.

After the screens, the pulp was diluted to .5%, so that it could be run through a two-stage Bird Tricleaner system. Following the Bird system was a one-stage bank of Voith-Morden Boi-Z cleaners. These cleaners are specially designed to remove light rejects. The consistency was kept the same, but the differential pressure on the Boi-Z cleaners was very low (about three feet of head) compared to the Bird cleaners.

Following the cleaners, the pulp flow was split up. Half went to a flotation cell and half to a sidehill screen. The flotation cell was a Voith-Morden production size cell (1500 liter). It was run at .5% consistency for about 35 minutes. Since the cell has a turnover time of about 3 minutes, the time used is roughly equal to 11 cells in series. The only additive in the cell was 1.5% soft soap (Ivory Flakes). After being deinked, the stock was thickened to about 15% for storage by using a muslin bag. The bag helps in the retention of fines.

The other half of the stock was sidehill washed using an 80 mesh screen on a one-pass system. The length of the screen (about 9 feet), was adequate to give good washing in just one pass. The stock was again thickened to about 15% for storage by using a muslin bag.

Once the deinking stage had been concluded, the bleaching stage could begin. The flotation cell and sidehill stocks were bleached in the same manner so that comparisons could be made at a later time.

There are four different bleaching sequences by which the stock was bleached. The first was a one-stage hydrogen peroxide bleach. The most important thing in this type of bleach is to make up an accurate and uniform bleach liquor. Below is a formula for the chemical make-up of the liquor. The amount of alkali added was calculated to give a total alkalinity of 1.4% based on bone-dry pulp. The magnesium sulfate was first added to the water, then the silicate, the caustic, and finally the peroxide. Failure to do this may have resulted in the unwanted precipitation of some chemicals. There were two different solutions for different addition rates. This way,

the total alkalinity on the pulp did not change, only the percent of hydrogen peroxide did.

H_2O_2 Liquor Make-up

.8%	Chemical	Amount Added	Concentration (g/l)	Addition%
	Water	1000ml		
	Magnesium Sulfate	.68g	.68	.05%
	Sodium Silicate	68g	68	5.0%
	Hydrogen Peroxide	10.9g	10.9	.80%
	Sodium Hydroxide	10.9g	10.9	.80%

Add 73.4ml of liquor per 100 grams of bone-dry pulp.

1.2%	Chemical	Amount Added	Concentration (g/l)	Addition%
	Water	1000ml		
	Magnesium Sulfate	.45g	.45	.05%
	Sodium Silicate	45.5g	45.5	5.0%
	Hydrogen Peroxide	10.9g	10.9	1.2%
	Sodium Hydroxide	7.3g	7.3	.80%

Add 110ml of liquor per 100 grams of bone-dry pulp.

The actual bleaching was quite easy. A 100g sample of pulp was adjusted to a consistency of 12% and a temperature of 160° F. This was done by placing the beakers of pulp in a water bath. A sheet of plastic was used to cover the beakers and bath so that the temperature would stay constant. This also prevented bleach liquor from being exposed to the air. The liquor was mixed in with the pulp using a small, hand mixer. After mixing, the pulp and liquor was allowed to stand in the constant temperature bath for one and one-half hours.

It was then neutralized to a pH of 9.0 using SO_2. The pulp was then washed on a 100 mesh hand screen. This was done by allowing the screen to fill with water and drain two times. British sheet mold handsheets were finally made and tested for brightness, TAPPI opacity, tear, mullen, and tensile.

The second bleach stage was a very simple, one-stage hydrosulfite procedure. Zinc hydrosulfite was used in this study due to its better stability. 50 grams of the pulp was adjusted to a consistency of 3% and a temperature of 160° F. This was done in the bath and covered like before. The plastic cover over the temperature bath helped in keeping the hydrosulfite from decomposing with air. One-half percent TSPP was added before the hydrosulfite was mixed in. After the bleach had been added, the stock was allowed to stand at a constant temperature for 45 minutes. It was then washed similarly to the peroxide sequence. Handsheets were once again made and tested.

The third stage was a combination of the first two. 100 grams of pulp started out at 12% consistency and 160° F. Peroxide liquor was added at .8% and 1.2% levels and allowed to set for 1.5 hours. Sulfer dioxide was used to lower the pH to 6.0 before the pulp was washed and prepared for the hydrosulfite stage. All of the conditions were the same as in the one-stage bleach, including the addition levels. Handsheets were eventually made and tested.

The last bleaching sequence to be run was a hypochlorite-hydrosulfite, two-stage procedure. The first thing that had to be done here was to make and test the quality of the bleach liquor. Chlorox bleach was used as a source of hypochlorite. By adding 820ml of water to 180ml of bleach, the concentration ended up quite close to 10.4 g/l. The concentration was tested by mixing together 150ml H_2O_2, 5ml HCL,

25ml bleach liquor, and 5g KI. The mixture was easily back-titrated with .2N thiosulfate.

The preliminary conditions for this bleach sequence was 100 grams of pulp at 8% consistency, 110° F, and pH of 9.5. The hypochlorite was then added at levels of 1.5% and 3.0%. After the pulp sat for 1.5 hours, the pH was adjusted to 6.0 with SO_2. After the pulp was washed, the conditions were adjusted to 160° F and 3% consistency, Typical hydrosulfite sequences were then run using the same .8% and 1.2% addition levels. When the bleaching steps were finished, hand-sheets were made and tested.

The appendix of this report contains the experimental procedure in a flow chart form. The flow chart form is sometimes easier to follow than any other.

Results

The experimental results are shown in tables one and two. The top half of each table contains results from testing done on the stock that was flotation cell deinked. The bottom half contains the results for the sidehill washed stock. The errors noted in the table are standard deviations due to sample testing.

Three of the best bleaching sequences were redone to get a repeatability error. For brightness, this repeatability error was ±.68 (1.2%). Opacity had a repeatability error of ±.39 (.43%).

A calculation was made to get the average standard diviation due to sample testing. This value for brightness and opacity came out to be ±.39 (.8%) and ±.42 (.45%), respectfully. The other values were: tear factor ±.4.2 (5.5%), mullen factor ±.93 (7.8%) and breaking length ±240 (7.4%).

Color measurements were made for each sample, but not included in the tables, because the values didn't make any significant changes. The dominant wavelength was 575 nm. The purity for the handsheets was 15%.

Samples of stock were taken at every point in the study from which handsheets were made. The appendix contains samples from most of these points.

Table three contains the results of a Clark classification done on the two types of unbleached stock. The standard deviation after running two classifications of each stock was negligable. The freenesses are included for analysis.

Table I

Flotation cell stock	Unbleached	1-Stage Hydrosulfite .8%	1-Stage Hydrosulfite 1.2%	2-Stage H_2O_2 .8%	2-Stage H_2O_2 1.2%	2-Stage H_2O_2 Hydrosulfite .8 -.8%	2-Stage H_2O_2 Hydrosulfite .8 -1.2%	2-Stage H_2O_2 Hydrosulfite 1.2 -.8%	2-Stage H_2O_2 Hydrosulfite 1.2 -1.2%	2-Stage Hypochlorite-Hydrosulfite 1.5 -.8%	2-Stage Hypochlorite-Hydrosulfite 1.5 -1.2%	2-Stage Hypochlorite-Hydrosulfite 3.0 -.8%	2-Stage Hypochlorite-Hydrosulfite 3.0 -1.2%
BTNS	43.7 ±.5	46.3 ±.3	48.5 ±.3	50.6 ±.3	52.3 ±.4	52.5 ±.3	53.0 ±.1	53.2 ±.2	54.5 ±.3	44.0 ±.3	44.8 ±.5	41.0 ±.6	43.0 ±.6
OPAC	96.9 ±.1	96.1 ±.3	95.4 ±.1	94.4 ±.6	94.4 ±.4	94.0 ±.3	93.8 ±1.0	93.8 ±.4	94.4 ±.5	95.3 ±.2	95.7 ±.3	96.5 ±.5	95.9 ±.3
Sidehill stock													
BTNS	43.6 ±.4	46.8 ±.8	48.6 ±.5	49.9 ±.4	51.4 ±.2	52.2 ±.6	52.5 ±.4	52.0 ±.4	53.8 ±.3	43.3 ±.3	45.7 ±.6	40.4 ±.2	43.4 ±.3
OPAC	95.7 ±.4	93.9 ±.5	93.6 ±.4	93.8 ±.5	92.2 ±.4	91.5 ±.2	90.0 ±.4	90.4 ±.3	90.6 ±.8	94.6 ±.4	94.0 ±.6	94.8 ±.6	94.5 ±.5

Table 2

Flotation cell stock	Unbleached	1-Stage Hydrosulfite .8%	1-Stage Hydrosulfite 1.2%	1-Stage H_2O_2 .8%	1-Stage H_2O_2 1.2%	2-Stage H_2O_2 Hydrosulfite .8 -.8%	2-Stage H_2O_2 Hydrosulfite .8 -1.2%	2-Stage H_2O_2 Hydrosulfite 1.2 -.8%	2-Stage H_2O_2 Hydrosulfite 1.2 -1.2%	2-Stage Hypochlorite-Hydrosulfite 1.5 -.8%	2-Stage Hypochlorite-Hydrosulfite 1.5 -1.2%	2-Stage Hypochlorite-Hydrosulfite 3.0 -.8%	2-Stage Hypochlorite-Hydrosulfite 3.0 -1.2%
Tear factor	86.8 ±3.4	78.4 ±4.5	77.2 ±4.0	75.9 ±5.0	71.7 ±2.9	72.4 ±4.3	72.2 ±4.4	69.5 ±4.2	66.7 ±5.0	72.8 ±3.6	71.6 ±1.6	66.6 ±5.2	68.7 ±4.8
Mullen factor	16.5 ±1.4	14.7 ±1.0	14.0 ±1.0	12.2 ±1.3	13.3 ±1.5	13.7 ±1.1	13.4 ±1.2	13.5 ±1.2	12.6 ±1.8	13.5 ±1.2	13.2 ±.8	12.9 ±1.2	12.9 ±1.3
Breaking length (meters)	4400 ±400	4250 ±100	3660 ±200	3780 ±250	3565 ±380	3550 ±350	3800 ±500	3550 ±100	3450 ±300	3850 ±200	3700 ±200	3170 ±300	3300 ±150
Freeness	283									244	284	244	310
Side-hill stock													
Tear factor	86.2 ±2.6	85.2 ±4.0	83.9 ±4.0	80.2 ±2.7	82.3 ±3.0	81.8 ±4.2	82.1 ±4.9	79.8 ±5.0	77.9 ±3.5	82.0 ±3.0	81.0 ±4.0	76.0 ±3.0	74.2 ±3.5
Mullen factor	9.9 ±1.3	10.9 ±.9	9.0 ±1.0	9.0 ±.2	9.4 ±.8	11.8 ±.5	11.2 ±.4	11.8 ±.8	12.0 ±1.2	10.2 ±.5	9.8 ±.5	10.3 ±.7	10.2 ±.4
Breaking length (meters)	3550 ±240	3470 ±200	3200 ±300	2960 ±250	3170 ±200	3250 ±200	3200 ±200	3300 ±200	3200 ±300	2970 ±140	2870 ±200	2470 ±150	2380 ±130
Freeness	507									490	507	499	514

Table 3

Clark Classifications

Mesh	Flotation cell stock	Sidehill screen stock
14	.2%	1.3%
20	18.6%	27.2%
50	25.5%	26.6%
100	20.1%	21.9%
Fines	35.6%	23.0%
Freeness (CSF)	283	507

Discussion

Due to some of the strange happenings in the deinking stage, this thesis, which started out to be a bleaching study, ended up being more of a deinking study. When one looks at the handsheet sample from the hydropulper (see appendix), the first thing that is noticed is the lack of the typical blue-gray color. Part of this is due to the washing effect of the handsheet machine, but only a small part. The bottom exiting style of this hydropulper prevents larger material from leaving. In this study, the held back material included mainly wet strength paper and plastic. Close examination of the plastic shows that it attracted and retained ink particles. A sample of this plastic is included in the appendix. The sample, which started out as clear plastic, is now nearly all black. All of the plastic that was in the hydropulper attracted ink. Each type, however, attracted the ink to a different degree. According to Sparks and Puddington,[6] this phenomenon is due to the hydrophobic nature of both the ink and plastic. Evidently, as the hydrophobic nature of each plastic varies, so does its attraction towards ink particles.

After the pulp had been transferred to a chest, it was noticed that the foam on top of the pulp (due to the surfactant) was almost black, due to the ink contained in it. This foam and ink mixture must have been quite stable, because it was not broken down at all by the chest agitator.

The trial went as expected up to the Bird Tri-cleaners. At this point, it was noticed that a large amount of ink was coming out in the heavy reject stream. The quantity of ink being removed here was actually quite large. Handsheet samples show this fact (see sppendix).

A possible explanation is that either the ink particles agglomerated to form larger, heavier particles, or they attached themselves to the heavier particles in the system, which included a large amount of inorganic material (sand, clay, etc.). The latter reason seems more believable, because the sample bucket from which post-screen handsheets were made contained a number of clay-ink agglomerations in the bottom. A post-cleaner sample still contained a few of these particles, but not as many as before.

At this time, the stock still contained a large amount of ink in the foam. Unfortunately, the trial had to be halted here due to a lack of time. The pilot plant people were to be gone the following day, so the stock was stored in a chest from five o'clock on Wednesday until eight o'clock on Friday. During this time, the foam on the pulp had broken down. The chest agitator brought back the foam, but the ink which had been contained in it, was missing. When the Boi-Z cleaners were run, everyone felt the results would have been better if the ink had been contained in the foam, since these cleaners are made to remove mainly foam.

Both the sidehill screen and flotation cell gave a final product that was very clean and contained little ink. The clay agglomerations that were mentioned earlier were not removed at all by the sidehill, because they were much larger than the screen mesh. The flotation cell, however, was able to float off a good portion of these particles, as the sample handsheets will show.

The large freeness difference between the flotation cell and sidehill prompted a Clark classification of each stock. The results (table 3) show that the sidehill lost mainly fines, which explains

its high freeness. The flotation cell, however, floated off mainly long fiber, which explains its lower freeness.

The pulping and cooking stages were repeated several times on a laboratory scale. The plastic did attract the ink, but not as much as had been found in the pilot plant. This is probably due to the fact that the plastic pieces in the blender kept winding around the rotor shaft, where they would bunch up and not be exposed to the ink particles.

The bleaching sequence results were more predictable than those in the deinking stage. The brightnesses of the two stocks started out the same, but after every bleaching sequence, the sidehill stock came out a little lower. The sidehill stock contained the clay agglomerations. These agglomerations contained very minute ink particles that gave them an overall gray color. The agitation of the pulp during the bleaching stages probably broke up and dispersed a few of these particles, leaving the stock with a slightly gray color (not seen with the eye) and a lower brightness.

It was expected that the hydrosulfite bleach alone would give approximately three to eight points of brightness and the peroxide would give a little more. The two-stage peroxide-hydrosulfite should have given a little less than the sum of the one-stage increases. All of these expected results came true.

The unexpected brightness results came from the hypochlorite-hydrosulfite stage. It was expected that the hypochlorite would give a slight brightness gain, followed by a larger gain due to the decolorization of the hydrosulfite. What happened was that the initial brightness gain by the hypochlorite decreased with time and eventually

turned yellow. The hydrosulfite gave a brightness gain, but not enough to counteract the bad effect of the hypochlorite. This bleaching sequence was not expected to be very good, but it was expected to do better than it did. Evidently, either much more, or less hypochlorite must be added to make this an adequate bleaching sequence.

The opacity of the flotation cell stock was higher than the sidehill stock due to the different amounts of fines present. As expected, the harder bleached stock had a lower opacity. This is due to many things, including the reduction of color in the sheet.

The strength tests were taken as a indicator to see what happens to the sheet as it is bleached. The tear test gave pretty good results. Longer fibers generally mean a higher tear value. Since the sidehill stock has a higher percentage of longer fibers, one would expect its tear values to be slightly higher than those of the flotation cell stock. All of the bleached results proved this to be true. The unbleached values are statistically the same, but by the same token, they may be as much as seven percent apart. As in all strength tests. one expects lower values with an increase in the amount of bleach applied. This too, was proven true by the results.

It was also expected that the hypochlorite-hydrosulfite values would be lower due to harsh action of the hypochlorite. Evidently, the amount of hypochlorite applied was small enough, so that it had little effect on the fiber. The results show a slight decrease, but one that is statistically insignificant.

The mullen results should be almost the opposite of the tear results, because mullen strength is dependant on bonding, which is

proportional to the amount of fines present. Since the flotation cell stock contains more fines than the other, one would expect to see higher mullen values in the flotation cell column. This is true throughout all of the results. The higher bleaching levels also had lower mullen values, as was expected.

The tensile factor (breaking length) is like a combination of mullen and tear. Both long fibers and bonding (fines) have an affect on the breaking length. By looking at the results from these tests, it is evident that fines had more of an affect than did long fibers. it is possible that the bonding caused from the extra amount of fines in the flotation cell stock was enough to offset the difference in long fiber. Even with the high standard deviations of the results, it is obvious that the breaking length of the flotation cell stock was better than that of the sidehill stock. There was also the usual trend of lower values at a higher bleaching strength.

The results of this study are pretty good in general. There are a few values that are off, but not too many. There are a few results in both the deinking and bleaching stages that may be the result of many factors. Fortunately, many of these factors have a very small affect on the results, so that only one or two factors have most of the affect.

Conclusion

This thesis project started out as a bleaching study, and ended up dealing with deinking more than anything else. This is alright though, because before any real conclusions can be made, the results must be tested over and over so that it is known that duplication is possible. This is why this study ended up dealing with deinking more than bleaching. The key results came in deinking, so this is what was worked with most. A list of the main conclusions of this thesis follows:

1. Deinking with the help of plastics is possible. When one views the results from the deinking process, it is obvious that the plastics had a major effect.
2. By using the proper equipment, the "garbage paper" type furnish can be cleaned up to an amazing degree.
3. With the use of a simple peroxide-hydrosulfite bleach, the brightness of this stock can be raised to the high fifties.

When one considers that the raw material for this thesis was essentially garbage, these conclusions become quite important. They are the key for the reuse of household wastes. It is actually possible to start with garbage right from the trucks, and end up with clean, deinked paper that has good brightness.

Recommendations

There are several things that should be done to follow this study. The following is a list of areas where more work should be done.

1. A study should be done concerning the use of plastics in deinking. Results should include what types of plastic are best, how much is needed, and what conditions are best.
2. The deinking stage should be repeated in the pilot plant. This study should be completed in one day to see the effect of removing ink while it is contained in the foam (using Boi-Z cleaners).
3. Actual pulp should be acquired from the National Center for Resource Recovery to see if the same results can be achieved using genuine garbage paper.
4. If the same results can be achieved on the NCRR pulp. there should be a study done concerning the feasibility of adding a pulp processing system to the present mill at New Orleans.
5. Possible end uses for a pulp of this sort include: newsprint filler, plasterboard covering, and anything else that could use a cheap, low-brightness pulp.

References

1. Jackson, F. R., Reclaiming and Recycling of Municipal Solid Wastes, London, Noyes Data Corp., 1975.

2. Baum, B., and Parker, C., Solid Waste Disposal Volume I - Incineration and Landfill, Ann Arbor, Michigan, Ann Arbor Science Publishers, Inc., 1973.

3. Aldrich, Lyman, Research Associate Dept. of Paper Science and Engineering, Western Michigan University, Kalamazoo, Michigan, several conferences

4. Schulz, K., "Mini Deinking Plant Supplements Pulp Needs for Printing Grades," Pulp and Paper, 48 #4 (April 1974)

5. TAPPI Monograph #31, Deinking of Waste Paper, 1967, p. 31-46.

6. Sparks, B. D., and Puddington, I. E., "Deinking of Waste News by Absorption of Contaminents on a Hydrophobic, Particulate Solid," TAPPI, 59 #11 (Nov.1976), p.117-9.

7. Mamers, H., and Menz, D., "Bitumen Removal From Wastepaper Furnishes," APPITA, 32 #2 (Sept.1978), p.119-23.

8. Tracy, Glenn, Georgia-Pacific Co., Seminar, #Comparison of BOD Loading, October 18, 1978.

9. Britt, Kenneth W., ed., Handbook of Pulp and Paper Technology, New York, Van Nostrand Reinhold Co., 1970, p.249-315.

10. Atwood, Harold S., Bus.-Man.-Hydrasulfites, Ind. Chem. Dept., Virginia Chemicals Inc., Portsmouth, Va., written correspondence.

11. Kindron, Robert R., Mgr. Pulp and Paper Tech. Service. FMC Corp., P. O. Box 8, Princeton, New Jersey, written correspondence.

12. Partridge, Harold D., Mgr. Paper Ind. Development, Hooker Chemicals Corp., Niagara Falls, New York, written correspondence.

13. Hedquist, Dale, Project Engineer, Blandin Paper Co., Grand Rapids, Minnesota, written correspondence.

14. Clouse, J. L., "Effect of Bleaching on Deinked Pulp," TAPPI, 49 #7 (July 1966), p.76-7.

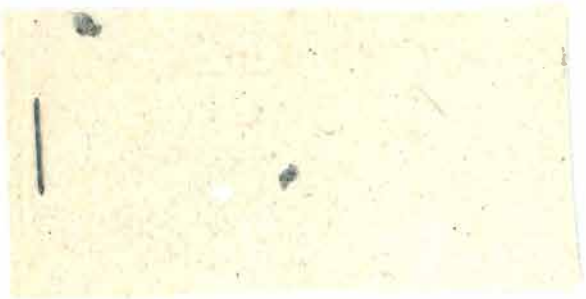
15. Gavelin, N. C., Science and Technology of Mechanical Pulp Manufacture, New York, Lockwood Publishing, 1966.

16. Richardson, C. A., "Two Stage Bleaching of High Yield Pulp at Blandin", TAPPI, 53 #2 (Dec.1970), p.2275-7.

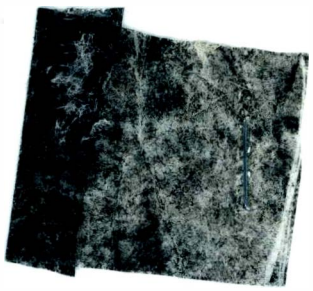
17. TAPPI Monograph #27, The Bleaching of Pulp, 1963.

18. Witkowski, C. J., "Groundwood Bleaching in Two Stages with Peroxides and Hydrosulphites", Paper Trade Journal, 156 (May 29,1972), p.25-9.

Appendix

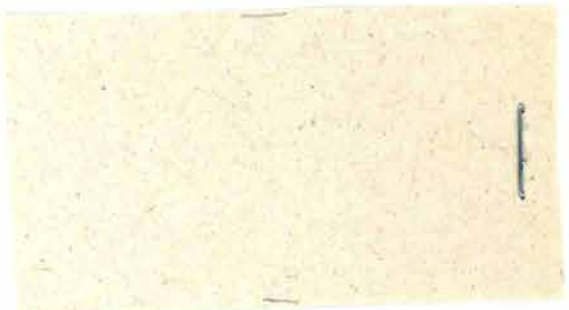


Hydropulper



Hydropulper Plastic

Johnsson Accepts



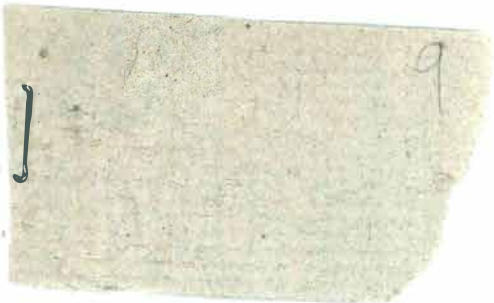
Selectifier Accepts

Tri-Clean Accepts

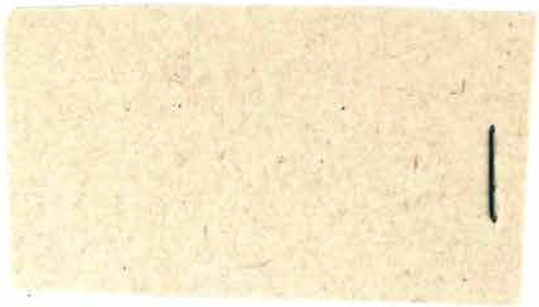
Tri-Clean Light Rejects

Tri-Clean Heavy Rejects

Boi-Z Accepts

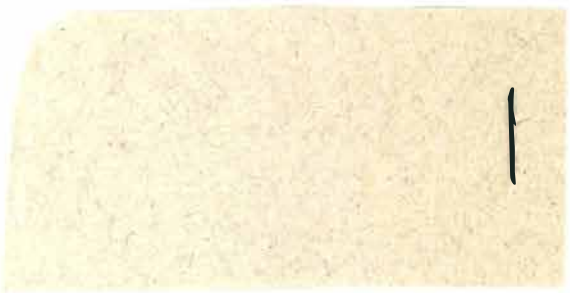


Boi-Z Rejects



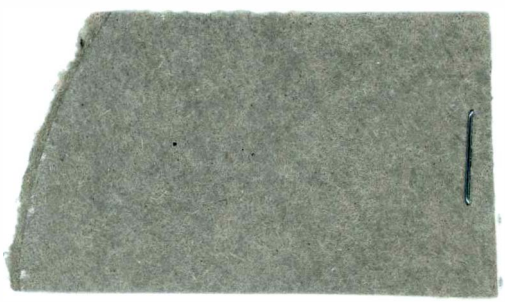
Sidehill Accepts

Sidehill Rejects



Flotation Cell Accepts

Flotation Cell Rejects-5 Min.



Flotation Cell Rejects-15 Min.

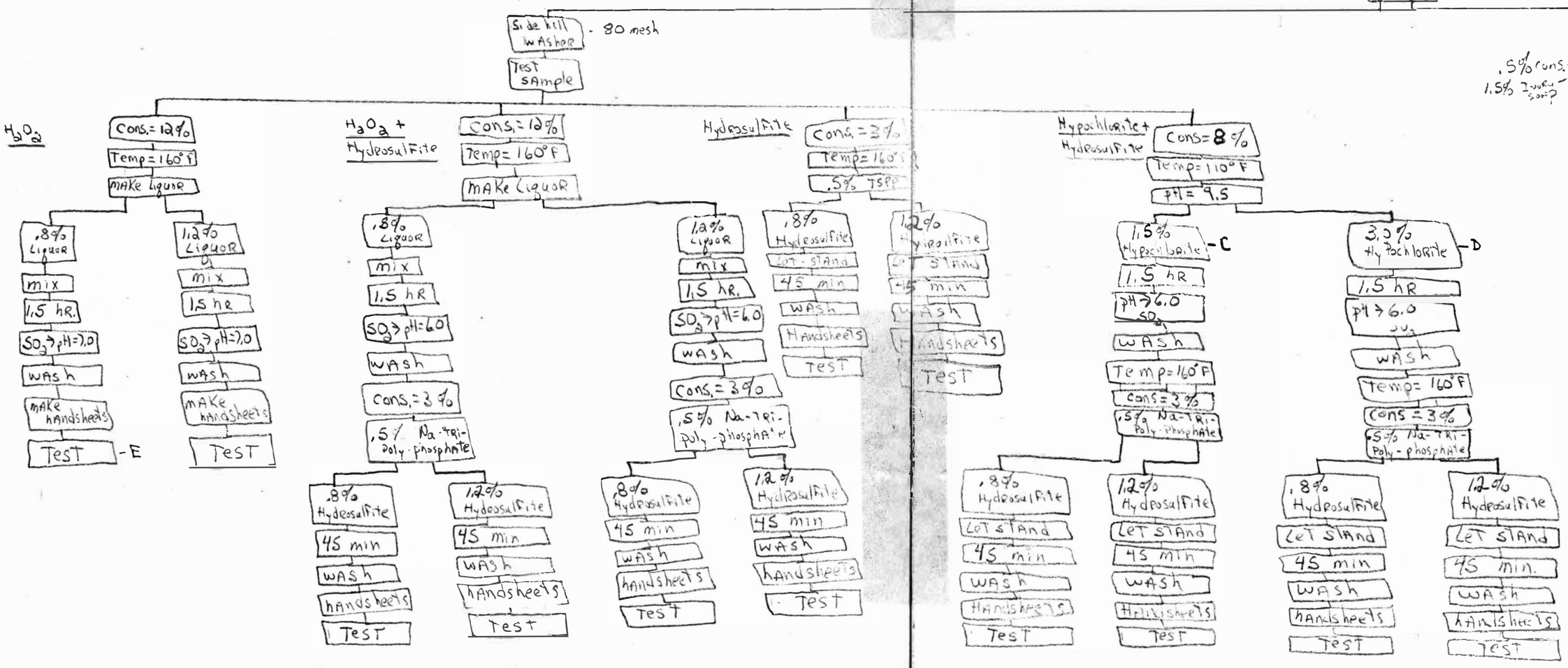
Flotation Cell Rejects-25 Min.

1.2-1.2% H_2O_2-Hydrosulfite Bleach Flotation Cell

1.2-1.2% H_2O_2-Hydrosulfite Bleach

Sidehill

Experimental Procedure



A- Add chemicals 2% Na_2O_2 (3 lbs.), 3% Na-silicate (4.5 lbs.), Triton X-100 (.3%)

B. Add Flotation cell chemicals - soap

C. Hypochlorite must be made and tested

D. "

E. Test for: Brightness (Pad + handsheet), opacity, tear, Mullen, tensile