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Utilization of Paper Mill Primary Sludge

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UTILIZATION OF PAPER MILL PRIMARY SLUDGE

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ABSTRACT

Recyclable fines and filler contribute to approximately one half the primary sludge stream, and is often disposed of instead of utilized to its fullest potential. With successful recovery of the fines and filler from the primary sludge, less raw material will be needed in the production of paper. This will decrease the cost of virgin material and the cost of disposing the sludge, while at the same time decreasing the volume of waste sent to landfills. Primary sludge was collected from a local paper mill and stored at the facilities of Western Michigan University. Solids and ash testing was done on the sludge in order to obtain background knowledge of the sample. Fiber length was performed using the Clark Classifier. Fines and filler material was separated from the primary sludge by means of a laboratory scale sidehill screen implementing a continuous process. After screening, fiber classification and ash tests were performed on both the accepts and the rejects collected. At this point handsheets were made at varying levels of recovered fines and filler material to determine the effects that increased addition levels had on the strength and optical properties of the handsheets. The tests used to evaluate the handsheets were brightness, tear index, tensile index, and zero-span tensile.

Results showed that recovered fines and filler material can be added up to 10% addition level without significantly affecting the strength and optical properties.

INTRODUCTION

With the government demanding the paper mills to institute a recycling program it is becoming more important to find new sources of raw material. Currently, in the paper industry, thousands of pounds of fiber and filler material are being flushed down the mills sewer where they are recovered, along with some other wastes, and sent to a landfill at the expense of the paper mill. A significant portion of this waste stream is composed of recoverable fines, calcium carbonate, clays and titanium dioxide. The common trend, in the paper industry, has been to landfill these waste instead of utilizing their potential as filler substitute in the paper making process. Successful recovery of this material would result not only in a savings for raw material but also in landfill cost. The goal of this thesis is to recover the fines and inorganics from the paper mill primary sludge and use it in place of the secondary fiber in recycled paper grades.

BACKGROUND DISCUSSION

Today the public is being made aware of the urgency to acknowledge the solid waste problem by carefully developed advertising schemes and mass media. The message to recycle is presented to the public every time they enter a grocery store, open a newspaper, or turn the television on. All this attention to the solid waste problem has made the consumer more interested in environmental concerns. It has become profitable to label a product as recycled in order to improve the marketability of the product. Recycling has hit almost every community through curbside recycling efforts made by environmental organizations.

Environmental organizations have targeted the large industries as the source of many of the solid waste problems that society faces today. One of the industries that has been condemned for it's contribution to the pollution dilemma are the pulp and paper mills. Over the past two decades, paper industries have made an effort to add a helping hand in the solid waste problem by recycling the waste generated from the production of paper. Although many of the accusations made about the paper industry are invalid, the paper industry realizes that there is a potential, in recycling the industries waste, to save money.

The largest source of paper industry waste is the sludge which leaves the paper mills. Sludge is defined as the solid material resulting from the clarification of pulp and paper mill effluent. The sludge stream is composed of a variety of waste generated in the paper making process such as shives, fibers, clay, and filler material. These suspended solids are separated in the primary clarifier by settling and are collected in the underflow as concentrated waste (1). The sludge is traditionally dewatered to approximately 40% solids by means of a two-stage process, utilizing a filtration process in the first stage and a pressing operation as the second stage of the dewatering process before being sent to a landfill (2).

Toxicity of the sludge sent to landfills is low enough not to cause concerns with the possibility of the contaminants leaching into ground water. However, the space available in current landfills is diminishing at an astronomical rate and it is becoming increasingly more difficult to open new landfills, due to stricter government regulations and communities not wanting a landfill in their backyards. These are the reasons that are raising the cost of having waste landfilled. At present they are rising and will continue too until a solution to our solid waste problem is put into action.

One logical solution to this problem is to switch to a closed mill operation. In other words, it would mean that no waste would leave the process and that any waste generated in the paper making process be recycled. Hence the sludge would be brought back into the mill as fiber and filler substitute. The difficulty with this is retaining the strength properties of the product, reduction in machine speed, buildup of bacteria (slime) in the mill, and retention on the machine.

An economical way of separating the fines and filler from the sludge is to implement a sidehill screen. This would produce efficient separation of the fines and filler material from the larger fibers, thus giving us two resources of fiber and filler substitute to reuse in the paper mill.

Studies have been conducted which focused on the separation and reuse of the fibers contained in the primary sludge. The results showed that blends of raw stock containing up to 7.5% reclaimed fiber from sludge have been used in the industry with only minimal effects on the pulp properties (3). To date minimal research has been conducted in the area of reusing the fines and filler material found in sludge. If the recovered fibers can be utilized in the paper making process as a source of fiber substitute then it should also be possible to use the recovered fines and filler material from the sludge as fiber/filler substitute.

PROBLEM STATEMENT

Primary sludge from a paper mill is composed of a significant amount of recoverable fines and filler material, which is currently being sent to nearby landfills instead of being recycled into the paper making process. Since the mills are not recycling this material they are spending more money on virgin filler material and the cost of having their sludge sent to a landfill. With successful recovery and utilization of the primary sludge the paper mills have the potential to reduce their cost be 1) not having to purchase virgin filler material and 2) reducing the volume of waste sent to landfills. This thesis was conducted to determine if this process of primary sludge utilization would be beneficial to the paper industry.

EXPERIMENTAL PROCEDURE

The sludge samples used for this project where gathered from a local paper mill over a four day period in order to decrease daily variations in the contents found within the primary sludge stream. One five gallon bucket of sludge was gathered daily from the underflow of the primary clarifier. At the end of the four days the samples were transported to the Western Michigan University pilot plant facilities were they placed in cold storage until testing began on the samples. At this point it should be noted that one of the samples was darker in color then the others indicating either higher ash content or increased biological activity. Two of the samples had a yellowish-cloudy appearance which was due to a large flow of starch to the primary clarifier. To decrease the possibility of biological activity from becoming a problem, knowing that two of the samples contained higher than normal percentage of starch, 1% formaldehyde was added to the two buckets. Before any testing was done the sludge samples were combined in order to insure a single uniform sample. At this point consistency and ash content of the uniform sludge sample was determined. The consistency of the combined sludge samples was 8.70% . Ash content was tested using the muffler furnace at 550 C and 900 C to determine the breakdown of the sludge sample between fines, calcium carbonate and titanium dioxide. The results from this test were 50.6% fines and other organics, 8.89% calcium carbonate and clays, and 40.51% titanium dioxide and other non combustibles. During this procedure the temperature of the muffler furnace was inadvertently increased from 550 C to 605 C causing concern over the validity of the results. Another ash test was done under closer observation to insure the accuracy of the results. The second set of data collected for the ash test were 50.1% fines and other organic material, 9.48% calcium carbonate and clays, and 40.42% titanium dioxide and other non combustible materials. The second ash tests results were similar to the data collected in the first test indicating the variation in temperature during the first test had minimal influence on the final results obtained for the ash tests. The sludge sample was then watered down from 8.70% consistency down to 1.0% consistency in order to insure proper running characteristics across the sidehill screen designed for this study. The sidehill screening process employed a continuous rather than a batch process. The sidehill screen was fitted with an 80 mesh screen, had foils inserted to increase drainage, and was run at a ten degree angle to simulate actual running conditions of a full scale sidehill screen. The headbox was constructed from a five gallon bucket and a specially designed headbox to deliver a constant flow across the width of the screen. Preliminary test were run using the scale model sidehill screen to determine optimum running parameters and to avoid complications during the actual run. Several modifications were made to the apparatus to improve it's characteristics. These modifications included the insertion of a weir inside the headbox, changing the slice opening on the headbox, construction of holding "tanks" for the accepts and rejects, not to mention sealing the headbox to make it water tight.

After the sludge was screened, fiber length of the feed, accept and reject streams were determined using the Clark Classifier. It should be noted here that the consistency of the accept stream was 4.8% and that of the reject stream was .52%. A target of five grams of oven dried fiber was used, and the Clark Classifier was run according to TAPPI standards. For the feed stream the following data was collected:

14 mesh	30 mesh	50 mesh	100 mesh	loss
.03 g	.38 g	.42 g	.62 g	3.55g

For the accept stream the following data was collected:

14 mesh	30 mesh	50 mesh	100 mesh	loss
.16 g	1.08 g	.78 g	.55 g	2.43g

For the reject stream the following data was collected:

14 mesh	30 mesh	50 mesh	100 mesh	loss
.01 g	.01 g	.02 g	.3 g	4.66g

These results show that 71% of the fine material was separated from the feed stream, while 48.6% of the accept stream constituted fine material, and 93.2% of the reject stream was fine material smaller than the 100 mesh screen. This data also shows that the sidehill screen was only 31.5% efficient at seperating the raw sludge stream on the first pass.

At this point the rejects from the sidehill screen were allowed to settle for a week. The excess water was then removed in order to have a concentrated sample with which to deal. The base stock was made of a 50% James River Burgess hardwood/ 50% Dry Den DCX softwood blend. The virgin hardwood/softwood blend was refined in a laboratory Valley Beater under a ten pound load until a freeness of 350 CSF was reached. The total refining time was eighty-five minutes, the final freeness 326 CSF, and the final consistency was 1.71%.

Noble and Wood handsheets were made with varying percentages of reclaimed fines and filler at a target of 2.5 g per sheet. The white water was first brought up to the point of saturation and then used in place of fresh water during the handsheet making process. This was accomplished by making a large number of handsheets with the reclaimed fines and filler until the consistency of the water reached an equilibrium. The saturation point occurred when the white water consistency reached .00756%. The white water was recirculated to better simulate machine conditions. Handsheets were made at 0%, 5%, 10%, and 15% reclaimed fines and filler. During the handsheet making process drainage time and formation were monitored. The data collected for drainage time is as follows:

Concentration	Drainage time (sec.)
0%	25
5%	29
10%	33
15%	43

By visual inspection, the formation remained constant and there was no noticeable difference between the formation at the various percentages of reclaimed fines and filler.

Tests performed on the handsheets included tearing resistance using the Elmendorf Tearing Tester, Tensile strength using the Instron Tensile Tester, zero-span tensile, brightness using the S-4 Brightness Tester, and ash to determine first pass retention.

RESULTS

A summary of the results obtained during testing of the samples used to evaluate the feasibility of recycling the fines and filler material found in the primary sludge stream are shown in table 1.

TABLE 1

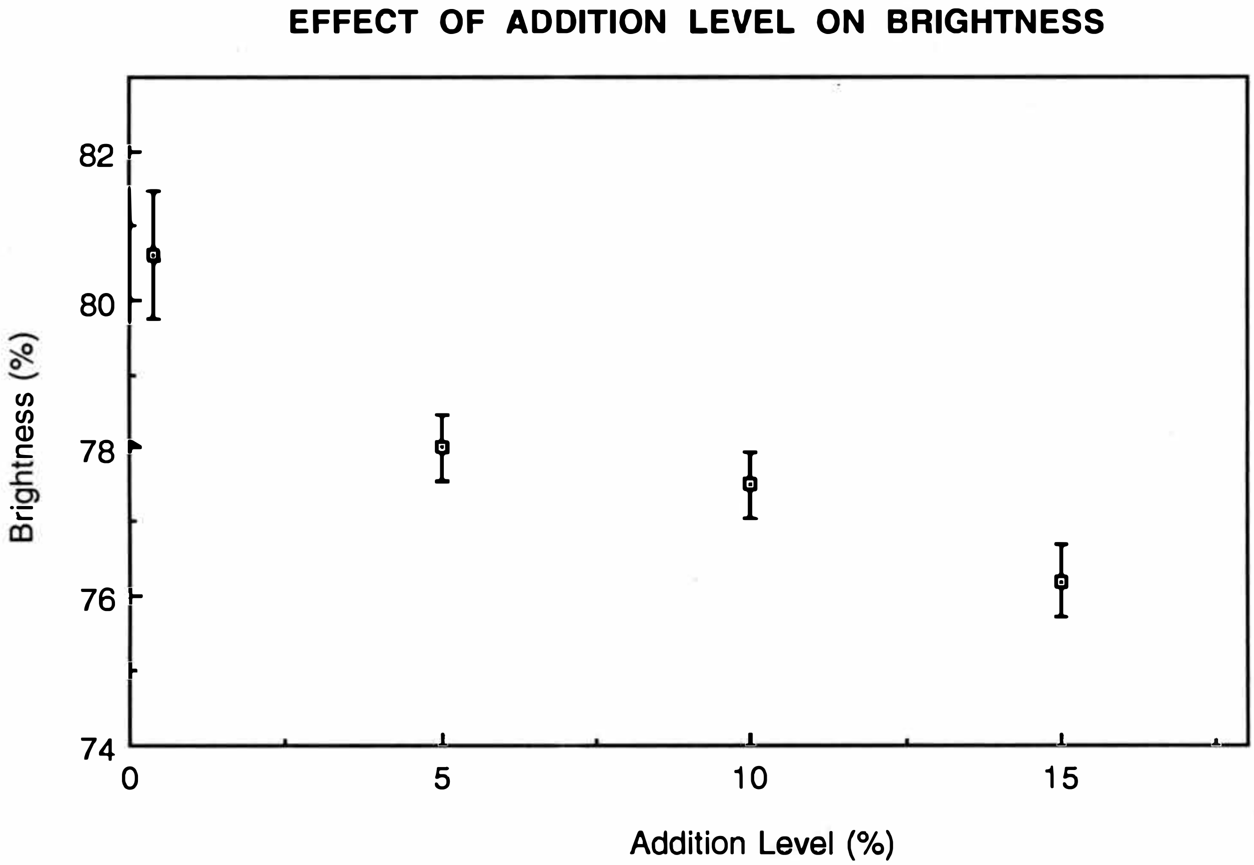
Percent Addition (%)	Tear Index (mNm2/g)	Tensile Index (Nm/g)	Zero Span Tensile (psi)	Brightness Level (%)
0	.615	67.7	24.1	80.6
5	.576	59.0	24.3	78.0
10	.584	51.8	21.9	77.5
15	.430	43.3	18.2	76.2

Tear index increased from 5% addition level to 10%, then had a drastic decrease in value at the 15% addition level.

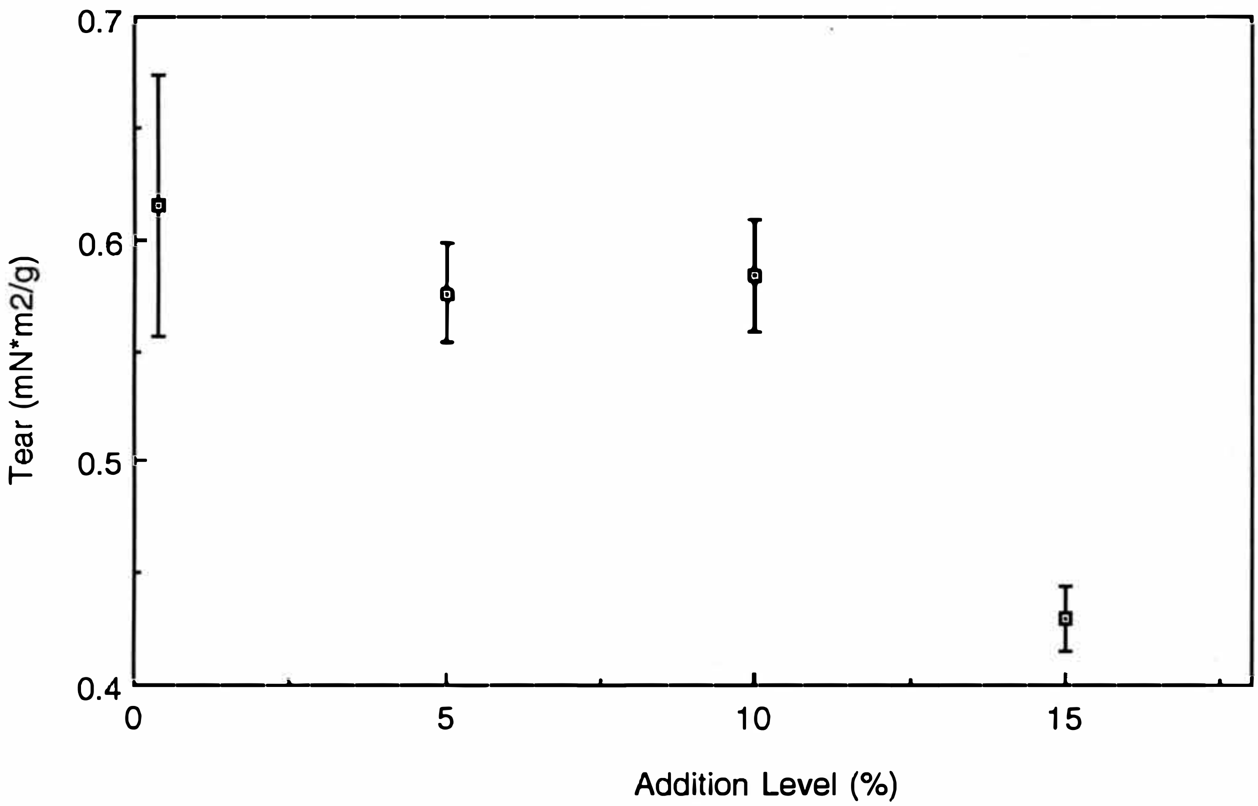
Tensile decreased almost linearly from 0% addition to the 15% addition level with minimal variance, from the straight line, in the values.

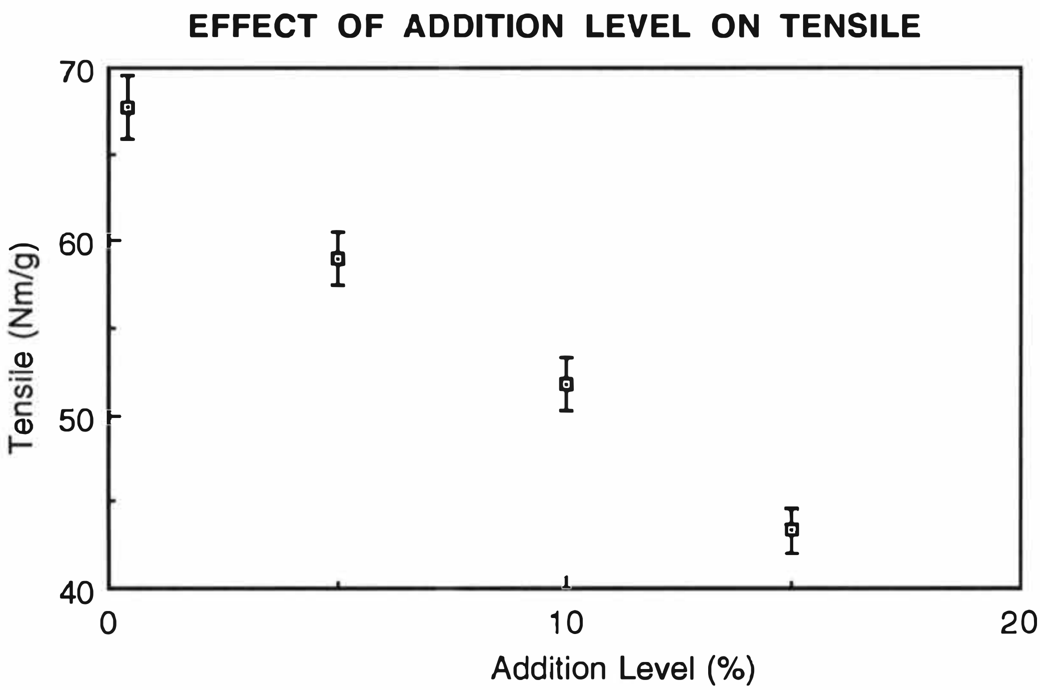
Zero-span values increased slightly from the control of 0% recovered fines and filler, then decreased at a near linear rate until 15% addition level was reached.

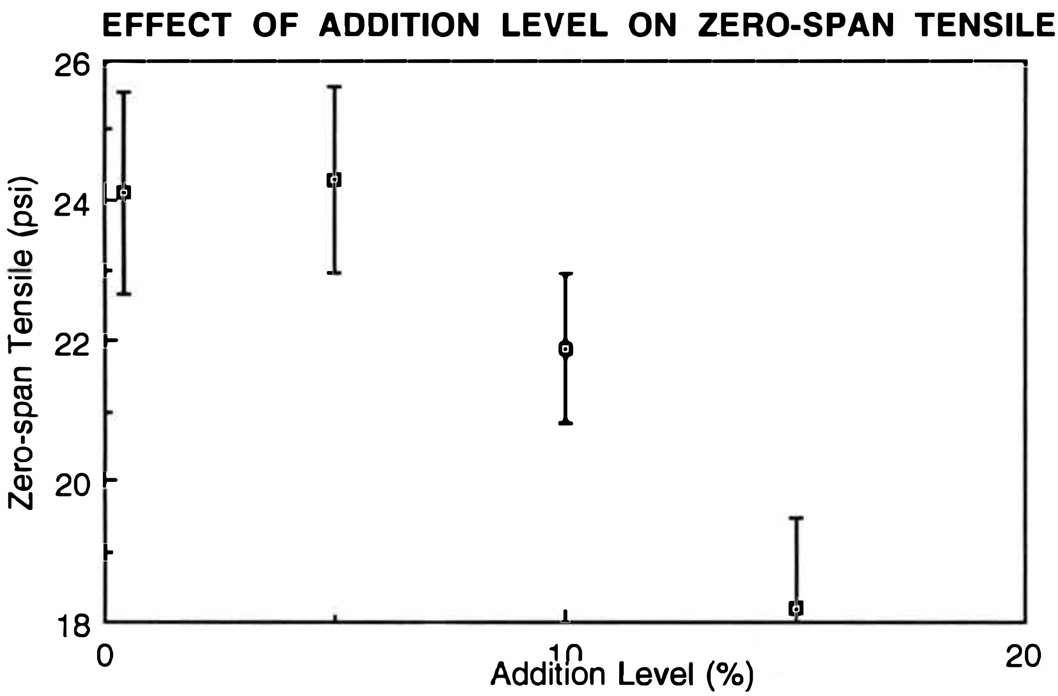
Brightness dropped drastically at 5% addition level after which they remained fairly constant, decreasing slightly as the amount of fines and filler material added was increased.


EFFECT OF ADDITION LEVEL ON BRIGHTNESS
82
80
78
76
74
Brightness (%)
0
5
10
15
Addition Level (%)

EFFECT OF ADDITION LEVEL ON TEAR




EFFECT OF ADDITION LEVEL ON TENSILE
Tensile (Nm/g)
70
60
50
40
0
10
20
Addition Level (%)


EFFECT OF ADDITION LEVEL ON ZERO-SPAN TENSILE
Zero-span Tensile (psi)
26
24
22
20
18
0
10
20
Addition Level (%)

DISCUSSION

The direct measurement of the force needed to tear paper is difficult because of the various potential work consuming mechanisms that are involved. These mechanisms are further complicated by the mode with which the tear measurement is made. The Tear Index measures the sheet resistance in the shearing or torsion tearing mode (4). In other words, tear index is a measure of three variables the first being the amount of work required to pull loosely bonded fibers out of the web intact, the second being the amount of work required to break the hydrogen bonds, and the third being the number of fibers which participate in sheet rupture (5). It should be noted here that the work required to pull a fiber out of the network is greater than the work required to break the fiber-fiber bonds. The results for tear index show a trend to decrease from samples tested wih 100% virgin stock to those containing recycled fines and filler material. This is due to increased fiber-fiber bonding while at the same time decreasing the amount of long fibers in the handsheets and the number of fibers across the rupture line. It should be noted that although the value obtained at 10% addition level increased from the previous value this fluctuation is attributed to the inherent error characteristics of the testing procedure.

Tensile index measures the forces per unit width required to break a specimen (6). The factors which influence the values are the same as those which effect tear index. As the point of failure is approached, more bonds fail in the rupture region and the remaining fibers take more of the sheet load, until the fibers lying in the direction of loading reach their rupture strain.

At this point, failure of the paper occurs. This is summarized by the following equation:

$$1/T = 9/8Z + 12Apg/BPL(RBA) \quad (7)$$

where

T = tensile strength of the strip

Z = finite-span tensile strength

A = average fiber cross section

p = density of the fibrous material

g = acceleration due to gravity

B = shear bond strength per unit bonded area

P = perimeter of the fiber cross section

L = fiber length

RBA = relative bonded area of the sheet

The values for tensile index decrease almost linearly for the samples tested at varying addition levels. This is attributed to the fact that as we increase the addition level we are decreasing the relative number of long fibers in the sheet, increasing the number of fines, and decreasing the average fiber length. As the data in the introduction shows, the recycled sludge stream is 73.1% ash. This indicates that we are receiving minimal fines from the recycled material to aid in the factors which increase tensile index. This explains why tensile index decreases as the addition level is increased. Zero-span is a measure of the force needed to break the fibers in a specimen and does not take into account the force needed to break bonds. This test is effected by the number of fibers, length of the fibers, and strength of the fibers across the rupture line. Since the addition of fines and filler material into the sheet effects all of these parameters it is reasonable to see that the values for zero-span decrease as the addition level is increased.

Brightness is defined as the reflectivity of a sheet of paper measured under standardized conditions and is used to indicate the degree of whiteness of the sheet (8). The results obtained show a decrease in brightness values as the addition level is increased. The reason for this is that the biological activity significantly affected the brightness of the reclaimed fines and filler material and hence had a noticeable effect on the brightness values of the handsheets.

CONCLUSIONS

There are several conclusions that can be made from this experimental work.

1. Screening with a sidehill screen is effective in separating the fines and filler from the sludge.
2. Drainage time is affected by the addition of recycled fines and filler material.
3. Noble and Wood handsheets can be made in the laboratory without noticeably affecting formation.
4. The strength properties of handsheets made with recycled fines and filler do not significantly decrease at addition levels up to 10%.
5. The brightness is not significantly affected at addition levels up to 15%.

RECOMMENDATIONS

The results from this project showed that it is possible, at least in a laboratory environment, to recycle the fines and filler from the primary sludge and further investigation should be done in this area.

First of all, a machine trial would prove useful to determine if this technique could easily and efficiently be implemented by the industry. If a machine trial were done it would be useful to ~~us~~ study the affects that varying the furnish, using retention aids, different pH ranges and the use of wet end starch had on, not only retention of the fines and filler but also strength and optical properties, in the final sheet. Next, a study on the printability of a sheet containing varying amounts of recycled fines and filler material reclaimed from the primary sludge. Finally, paper testing could be expanded to include IGT pick, burst, opacity, and smoothness to give more information on the effects of recovered fines and filler in the final sheet.

ENGINEERING DESIGN

The engineering design part of this project is the design of the process which was used to separate the fines and filler material from the primary sludge. The data obtained from this project showed positive results concerning the feasibility of utilizing the fines and filler material in the primary sludge. It seems it would indeed be beneficial mills within the industry to implement the recycling of this stream in order to reduce unwanted costs. The design would consist of pumping the sludge from the underflow of the primary clarifier to a sidehill screen where the fines and filler material was separated from the sludge. The rejects from the sidehill screen would then be pumped back to the mill, cleaned, and used in the raw stock make up.

COST ANALYSIS

A cost analysis was calculated to determine the feasibility of implementing this design on an industrial level. Sidehill screen capital costs and the associated pumping requirements. The average landfill disposal fees for the area were also used to determine the overall costs savings. The costs of current industry methods were compared to the costs of implementing the described recycling method. The results of this cost analysis are shown in Appendix VI.

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TAPPI Standard Method T 494 om-81

APPNDIX I

SLUDGE COMPOSITION DATA

	Fiber	$CaCO_3$	TiO_2/Clay
Raw Sludge	55.8%	3.84%	40.4%
Sidehill Accepts	74.6%	10.4%	14.9%
Sidehill Rejects	27.2%	9.87%	62.9%

APPENDIX II

CLARK CLASSIFIER DATA

Mesh	Raw Sludge	Sidehill Accepts	Sidehill Rejects
14	.03g	.16g	.01g
30	.38g	1.08g	.01g
50	.42g	.78g	.02g
100	.62g	.55g	.30g
Losses	3.55	2.43g	4.66g
Retention	29.0%	51.4%	6.80%

APPENDIX III

RESULTS

Brightness (%) Addition Level	Average	Standard Error
0%	80.6	.85
5%	78.0	.45
10%	77.5	.45
15%	76.2	.49

Tear Index (mNm^2/g) Addition Level	Average	Standard Error
0%	.615	.059
5%	.576	.022
10%	.584	.025
15%	.430	.014

Tensile Index (Nm/g)

Addition Level	Average	Standard Error
0%	67.7	1.77
5%	59.0	1.57
10%	51.8	1.50
15%	43.3	1.24

Zero-Span Tensile (psi)

Addition Level	Average	Standard Error
0%	24.1	1.44
5%	24.3	1.33
10%	21.9	1.06
15%	18.2	1.26

Standard Error = (Standard Deviation/(No. of Samples)$)^{1/2}$

APPENDIX IV

SAMPLE CALCULATIONS

Tear Index = 9.807 * force to tear one sheet / grammage

= mNm^2/g

Tensile Index = 653.8 * force to break 15 mm strip / grammage

= Nm/g

APPENDIX V

COST ANALYSIS

Sidehill Capital Cost	$9000
Pump Capital Cost	$7000
Pump Operating Cost	$1800
Total	$17800 for the first year