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Fiber Recovery from Paper Mill Primary Sludge

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FIBER RECOVERY FROM PAPER MILL PRIMARY SLUDGE

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TABLE OF CONTENTS

ABSTRACT

Recoverable fiber is a major component of paper mill primary sludge, and it is often landfilled instead of utilized to its potential. With successful recovery of fiber from sludge, less raw materials will have to be purchased and a lesser volume will be landfilled, thus decreasing landfill disposal costs.

Primary sludge from a local paper mill was collected and stored at Western Michigan University. Solids and ash testing was done first to get background knowledge of the sludge. Fiber length was then determined using the Clark Classifier. Fiber recovery was accomplished by using a laboratory scale sidehill screen. After screening, the Clark Classifier was again used to determine fiber length distribution. Handsheets were then made at varying levels of recovered fiber to determine the maximum amount of recovered fiber that can be added before strength properties decrease.

Results showed that recovered fiber can be added up to 10% to 12% recovered fiber without affecting brightness before a drop off in strength occurs. In light of current environmental awareness, this is a significant finding.

Recommendations for future work include a pilot machine trial and more involved handsheet project to gain more knowledge of the effect of recovered fiber on sheet properties.

INTRODUCTION

Usable fiber is a major component of primary paper mill sludge and is commonly landfilled instead of utilized to its potential. Successful recovery of fiber from sludge would result in both raw material and landfill cost savings. The goal of this thesis is to recover fiber from paper mill primary sludge and use it in place of secondary fiber for recycled type grades.

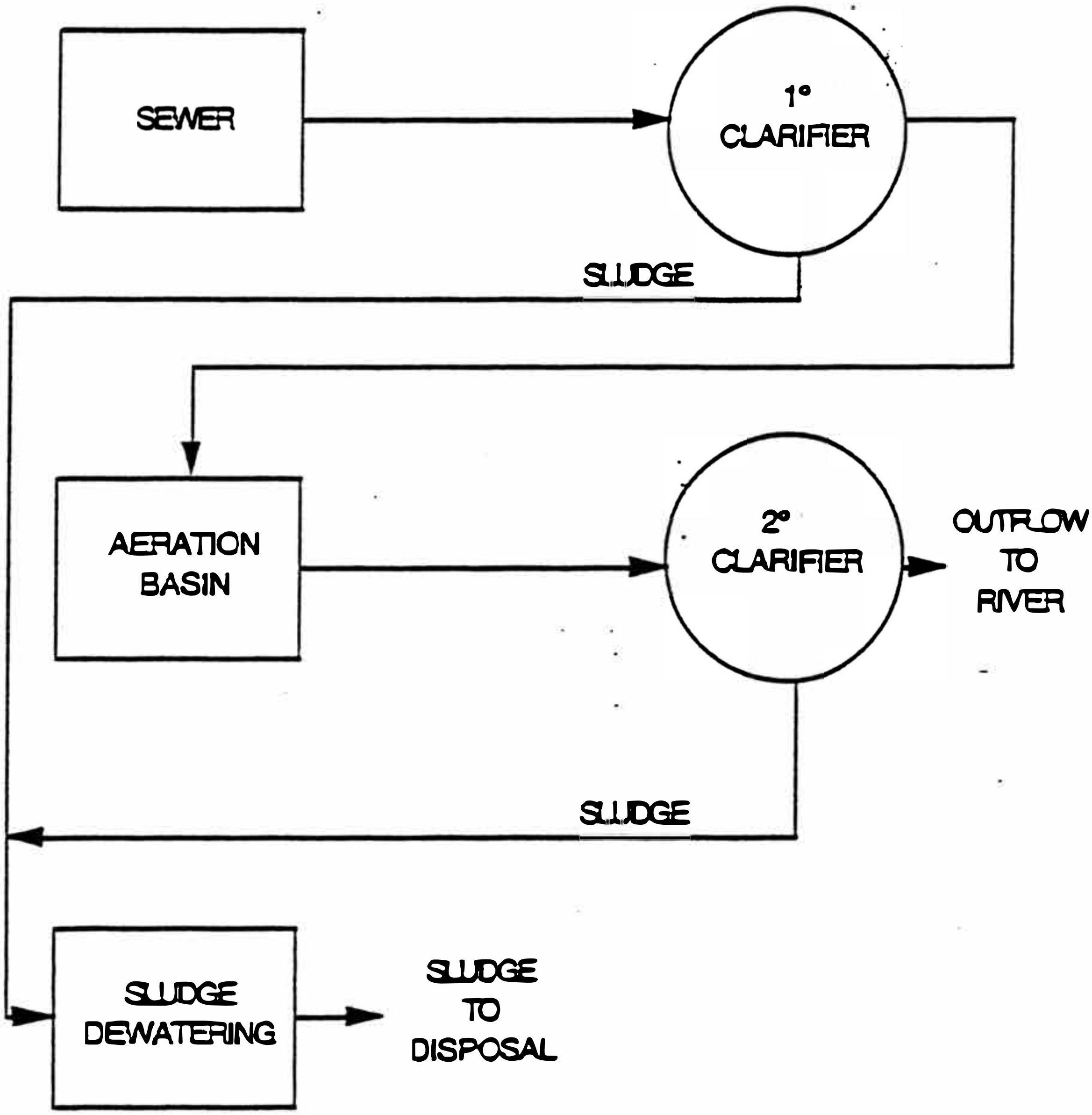
BACKGROUND DISCUSSION

Increased public awareness has renewed national interest in environmental issues. Consumers have become more aware of the solid waste crisis, and many people are buying recycled products and producing less waste. Recycling of household wastes, such as newspaper, glass, plastic, and metal have become commonplace in many communities.

The paper industry has been the target of much criticism and recycled paper has been demanded by the public. Environmental groups have condemned the paper industry for bleaching with chlorine, destroying forests, polluting the rivers and lakes, and filling landfills with toxic sludges. Most of these accusations are invalid and largely blown out of proportion.

Sludge is defined as the solid material resulting from clarifying pulp and paper mill effluent. Suspended solids, such as fiber and filler, settle in the clarifier and are collected in the underflow as sludge. The sludge is then

TYPICAL WASTE TREATMENT FACILITY



typically dewatered to approximately 40% solids before disposal. Although most of the sludge produced by paper mill waste treatment facilities is currently landfilled, the toxicity is low and it does not pose a threat to groundwater contamination. Land available for landfills is rapidly declining, and siting new landfills is a long, tedious, and difficult process. Landfill costs are high, and it makes sense to look for alternatives to sludge disposal/storage. Despite propaganda from environmental groups, the recycling and disposal issues are driven by the solid waste crisis, particularly the shortage of landfill space, not the saving of trees (1).

One logical solution is to recover the fiber present in the sludge and reuse it in the papermaking process. Some problems with this include difficulty in obtaining adequate strength in the paper and retention on the machine. The term closed system is applied in cases where sludge or reclaimed fiber is returned to the mill with minimal water discharge (2).

One possible way of reclaiming the fiber from the sludge is to screen and wash the underflow with the settled fiber from the primary clarifier. Sand, grit, and other contaminants can be removed by screening. In times of pulp spills when excess fiber is sent to the clarifier and load is high, provisions can be made to either recycle the underflow into the bottom of the clarifier or to recycle the underflows into the sewer. Because pulp and paper mill effluent can fluctuate greatly from day to day, it is important that the clarifiers can work well under varying load conditions. Clarifier studies have shown that they remove the residual fibers and keep the effluent within the requirements of the discharge permit. The reclaimed fibers are being recycled without loss of quality of the market product (3).

The freeness of the reclaimed fiber is only 225 ml CSF as compared with 700 ml CSF for unrefined mill pulp. Blends containing up to 7.5% of recovered fiber have been used in the industry without significantly changing pulp properties, and handsheet studies have verified these claims (4). This source applies to unbleached kraft pulp, and this project was conducted to look at fine paper and the effluent from a non-integrated mill to see if a similar trend existed. If blends of recovered fiber from sludge and virgin fiber can be used effectively, there should be a point where it is economically beneficial to each mill, no matter what type of paper is produced.

PROBLEM STATEMENT

Recoverable fiber is often found in paper mill primary sludge, and it is currently landfilled instead of being used in the papermaking process. This corresponds to increased expenses for the mill in both raw materials and landfill disposal. With successful recovery of fiber from sludge, less raw material will have to be purchased and a lesser volume of material will be landfilled, thus decreasing landfill disposal costs. This project was conducted to determine the feasibility of recovering usable fiber.

EXPERIMENTAL

A laboratory analysis was employed to determine if fiber can be successfully recovered from paper mill primary sludge.

The sludge sample was obtained from a local paper company over a four day period to minimize any drastic fluctuations in sludge content. Each day, the sludge was gathered from the underflow of the primary clarifier and collected in five gallon buckets. The sludge was then transported from the mill to Western Michigan University, where it was kept in cold storage (approximately 45 F) until testing began.

Initially, a sample from each bucket was taken and tested individually for consistency and ash content. The raw sludge sample had an average consistency of 5.64%. Ash testing was done at 500 C and 900 C to determine the calcium carbonate and titanium dioxide fractions of the sludge. For all four buckets, there was an average of 54.91% fiber and organics, 3.59% calcium carbonate, and 41.49% titanium dioxide and other nonvolatiles. Although there was a noticeable difference between the amount of material present in the ash crucibles between 500 C and 900 C, this was not reflected in the results. To check the validity of these results, a second ash test was conducted. There was 54.97% fiber and organics, 1.92% calcium carbonate, and 43.11%

titanium dioxide and other nonvolatiles, which was similar to the previous results. Investigation of typical $CaCO_3$ and TiO_2 ratios used at the local paper company suggested that the higher TiO_2 levels were probably due to the grades run at the time of sampling and the coatings used during this time period.

Before any further work was done, the four buckets were mixed together to assure a uniform blend and percent consistency was determined. It was noticed that one bucket was much darker gray in color than the others, which may have been indicative of higher ash content or more biological activity.

The Clark Classifier was used for fiber length determination of the raw sludge. A target of 5 grams oven dried fiber was used, and the Classifier was run until classification was complete. The 14 mesh screen collected 0.02 g of fiber, the 30 mesh screen collected 0.44 g of fiber, the 50 mesh screen collected 0.44 g of fiber, and the 100 mesh screen collected 0.93 g of fiber for a total of 1.83 g of collected fiber. The sample contained 6.83 g of oven dried fiber, so there were 5.00 g of losses as fines and filler. A laboratory sidehill screen was used to remove the fiber from the sludge. The sidehill screen employed a batch rather than continuous process. A tray was simply dumped and poured down the screen, and the stock was collected in a tray of equal volume at the bottom of the screen. A hose was used to help wash fiber down the screen, but care was taken to use as little as possible. This procedure was repeated four times to obtain adequate filler and ash removal.

The sidehill screen trays had a volume of approximately 5 liters, the consistency in the tray was about 1.0% and it was thickened to near 1.5% consistency, the stock temperature was 15 C, and a 60 mesh screen was used at an angle of about 60 degrees.

Problems occurred initially in the slope of the screen and obtaining a good accept stream. At first, the slope was not large enough, and large amounts of water were required to wash the stock down the screen. This resulted in a dilute accept stream and water use was uncontrolled and inaccurate. The slope of the screen was then increased, and results were more favorable. Some water was still required to help wash the fiber down the screen, but it was more controlled and less water was needed.

After the sludge was screened, fiber length was again determined by the Clark Classifier. After screening, 0.26 g of fiber was collected by the 14 mesh screen, the 30 mesh screen collected 2.08 g of fiber, the 50 mesh screen collected 1.01 g of fiber, and the 100 mesh collected 2.17 g of fiber for a total of 5.52 g of fiber. The original sample was 7.34 g oven dried fiber, so there were 1.82 g of losses. These results were much more favorable than the raw sludge data, and there was an increase in fiber retention of the Classifier from 26.8% for the raw sludge to 75.2% with the screened sludge. This shows that the sidehill screen was effective in removing fines and filler from the raw sludge. After screening was completed, handsheets were made. The recovered fiber was added to 50% James River Burgess hardwood/50% Dry Den DCX softwood blend. The virgin blend was refined in a laboratory Valley Beater under a 10 lb. load for 65 minutes. The final freeness was 339 ml CSF and consistency was 1.79%.

Noble and Wood handsheets were made with varying percentages of reclaimed fiber at a target of 2.5 g per sheet. Initially, handsheets were made at 0%, 5%, 10%, and 20% reclaimed fiber. There were no problems with drainage or formation, which was a concern at the start of this project due to the presence of fines and fillers. Tests performed on the handsheets included folding endurance using the M.I.T. Folding Endurance Tester, tearing resistance using the Elmendorf Tearing Tester, tensile strength using the Instron Tensile Tester, and brightness using the Brightness Meter. All tests were performed according to Tappi Standards. Testing of these handsheets showed a decrease in strength properties between 10% and 20% recovered fiber, so additional handsheets were made at 12%, 14%, 16%, and 18% to determine the drop-off point. Brightness was also determined at each addition level to determine the effect of recovered fiber on brightness (See Appendices III & V).

Throughout the entire handsheet making trial, both drainage and retention were prime concerns. Before handsheet making began, it was thought that the fines and filler present in the sludge would slow drainage and perhaps hurt formation. However, that was not the case at all. By visual inspection, each handsheet from 0% to 20% recovered fiber drained at the same rate and formation was not hurt either.

RESULTS

Some significant results and observations arose from this project (see Appendix III).

Folding endurance remained fairly constant at 5% and 10% addition of recovered fiber, but dropped off sharply after that.

Tear index increased from the control of 0% recovered fiber, remained fairly constant until 14% addition of recovered fiber, and dropped dramatically afterward.

Tensile index decreased considerably from the control of 0% addition to 10% addition of recovered fiber and leveled out after that. However, there was some variation and fluctuation in tensile index values from 14% to 20% recovered fiber addition.

Brightness values remained constant from the control of 0% recovered fiber to the maximum of 20% recovered fiber.

The following table includes the raw data from the testing of each sheet property and corresponds to the above observations.

Percent Addition (%)	Folding Endurance (cycles)	Tear Index (mNm2/g)	Tensile Index (Nm/g)	Brightness Level (%)
0	293	.53	61.27	80.03
5	300	.58	49.59	79.61
10	254	.56	44.46	79.85
12	104	.56	45.06	79.66
14	151	.57	35.16	80.29
16	117	.55	47.90	80.72
18	71	.53	35.12	80.36
20	78	.50	42.37	79.53

DISCUSSION

The results from folding endurance and tear index seem to correlate well. Both tests show similar trends and suggest that recovered fiber can be added to a 50% hardwood/50% softwood virgin blend up to approximately 10% to 12% before significant decreases in strength properties occur.

Folding endurance remained fairly constant up to 10% recovered fiber and then dropped dramatically after that. This suggests that above 10% recovered fiber, the individual fibers can no longer withstand the bending of the folding action and folding endurance decreases.

The plot of tear index vs addition level (see Appendix V) shows that tear resembles a typical beater curve, as values increase from 0% to 5% recovered fiber, level off, and decrease after approximately 14% recovered fiber. The reason for this may be that the freeness is changing as recovered fiber is added, thus following the same change in freeness trends in the beater curve.

Tensile index values decreased immediately as recovered fiber was introduced into the handsheet. This observation was unexpected and is difficult to explain. One possible explanation is that the presence of the shorter recovered fiber makes bond strength lower along the axis, thus affecting tensile strength results more than folding endurance or tear strength. This is pure speculation, however, and more extensive research is required in this area.

Brightness values remained nearly unchanged from 0% to 20% recovered fiber. The brightness of the recovered fiber itself was about 69%, as compared to 80% brightness of the sheet. The brightness plot (see Appedix V) indicates that the recovered fiber was not added in high enough percentages to affect the brightness of the resulting sheet.

CONCLUSIONS

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

1. Screening with a sidehill screen is effective in removing fines and filler from sludge while retaining the longer fibers.
2. The sidehill screen is also effective in improving fiber length distribution by separating the long fibers needed in papermaking.

3. Noble and Wood handsheets can be made in the laboratory without adversely affecting drainage time or hurting sheet formation.

4. Handsheets can be made with up to 10% to 12% recovered fiber before strength properties decrease significantly.

RECOMMENDATIONS

The results from this project were favorable and further work should be done in this area.

First of all, a more sophisticated continuous sidehill screen should be used to eliminate some of inconsistencies of the batch operation used in this project. Secondly, if a continuous sidehill produces an improved accept stream, the feasibility of using the Kajaani Fiber Analyzer should be examined to give more precise results. Next, varying furnishes could be studied to determine what blend of hardwood and softwood pulp is optimum for recovered fiber addition. Fourthly, a pilot machine trial could be run to see if this is possible on an industrial scale. Retention and retention aids would most likely be of prime concern with a machine trial. Also, varying pH could be done to find the best pH range for adding recovered fiber. Finally, paper testing could be expanded to include burst, zero span tensile, brightness, and opacity to give a more well-rounded understanding of the effects of recovered fiber on the sheet.

ENGINEERING DESIGN

The engineering design portion of this project is the design of a process which will aid in the recovery of fiber from sludge. Since the results from this project have been favorable, fiber recovery at a paper mill's waste treatment facility seems possible. The design would consist of pumping clarifier underflow to a sidehill screen where contaminants, fines, and fillers are removed and fiber is reclaimed. This fiber would then be pumped to the mill, screened, and cleaned again and used in paper production.

COST ANALYSIS

A cost analysis was performed to determine the feasibility of implementing this design on an industrial scale. Sidehill screen capital costs and associated pumping requirements were obtained from industry, and typical landfill disposal fees for southwest Michigan were obtained from a local paper company. These costs were compared to determine the amount of fiber a mill would have to recover in the first year to pay for the screen, pump, and operating costs (see Appendix VI).

REFERENCES

1. Nichols, Alan B., "Making Inroads With Paper Recycling", Water Environment and Technology, 2 (9), p. 80 (September 1990).

2. Guss, Daniel B., "Closed Water Systems In Mills Using Secondary Fiber", Tappi Journal, 61 (6), p. 19 (June 1978).

3. Crotogino, H.F., "Money-Saving Idea: Recycle Fiber Sludge To Paper Mill", Pulp and Paper, 47 (9), p. 79 (August 1973).

4. Crotogino, p. 79.

5. Crotogino, p. 79.

BIBLIOGRAPHY

Blundell, K.D., "Pulp, Paper, And Board In The Environment", Paper, 179 (3), p. 118-122 (February 1973).

Church, Fred, "Effluent Measurement And Control At Reed Aylesford Complex", Pulp & Paper International, 13 (1), p. 37-38 (January 1971).

Crotogino, H. F., "Money-Saving Idea: Recycle Fiber Sludge To Paper Mill", Pulp and Paper, 47 (9), p. 79 (August 1973).

Forsell, B., "New Method Of Fiber Recovery From Pulp And Paper Waste Sludge", Paper Trade Journal, 155 (10), p. 34-38 (March 1971).

Guss, Daniel B., "Closed Water Systems In Mills Using Secondary Fiber", Tappi Journal, 61 (6), p. 19 (June 1978).

Nichols, Alan B., "Making Inroads With Paper Recycling", Water Environment and Technology, 2 (9), p. 80 (September 1990).

Savage, G. M.; Diaz, L. F.; Trezek, G. J.; "Fiber From Urban Solid Waste - Recovery Procedures And Pulp Characteristics", Tappi Journal, 61 (6), p. 15-18 (June 1978).

APPENDIX I

SLUDGE COMPOSITION DATA

	Fiber	CaCO3	TiO2
Raw Sludge	54.9%	1.9%	43.2%
Sidehill Screen Accepts	85.4%	3.3%	11.3%
Filtrate From Sidehill	42.2%	0.7%	57.1%

APPENDIX II

CLARK CLASSIFIER DATA

Mesh	Raw Sludge Retained	Screened Sludge Retained
14	0.02 g	0.26 g
30	0.44 g	2.08 g
50	0.44 g	1.01 g
100	0.93 g	2.17 g
Losses	5.00 g	1.82 g
Total Retention	26.8 %	75.2 %

APPENDIX III

RESULTS

Folding Endurance (cycles)

Addition Level	Average	Standard Error
0 %	293	7.90
5 %	300	63.00
10 %	254	34.21
12 %	104	30.16
14 %	151	23.89
16 %	117	19.57
18 %	71	8.33
20 %	78	18.22

Tear Index (mNm^2/g)

Addition Level	Average	Standard Error
0 %	0.53	0.018
5 %	0.58	0.013
10 %	0.56	0.013
12 %	0.56	0.009
14 %	0.57	0.004
16 %	0.55	0.009
18 %	0.53	0.013
20 %	0.50	0.009

Tensile Index (Nm/g)

Addition Level	Average	Standard Error
0 %	61.27	2.29
5 %	49.59	4.99
10 %	44.46	5.21
12 %	45.06	2.73
14 %	35.16	3.41
16 %	47.90	0.78
18 %	35.12	3.80
20 %	42.37	1.18

Brightness (%)

Addtion Level	Average	Standard Error
0 %	80.03	0.58
5 %	79.61	0.43
10 %	79.85	0.18
12 %	79.68	0.18
14 %	80.29	0.55
16 %	80.72	0.22
18 %	80.36	0.40
20 %	79.53	0.25

Statistics

Standard Error = Standard Deviation/(No. of Samples)^.5

APPENDIX IV

SAMPLE CALCULATIONS

Folding Endurance

Folding Endurance = Ave No of Cycles * 65 / grammage

= cycles

Tear Index

Tear Index = 9.807 * Force to Tear One Sheet / grammage

= mNm^2/g

Tensile Index

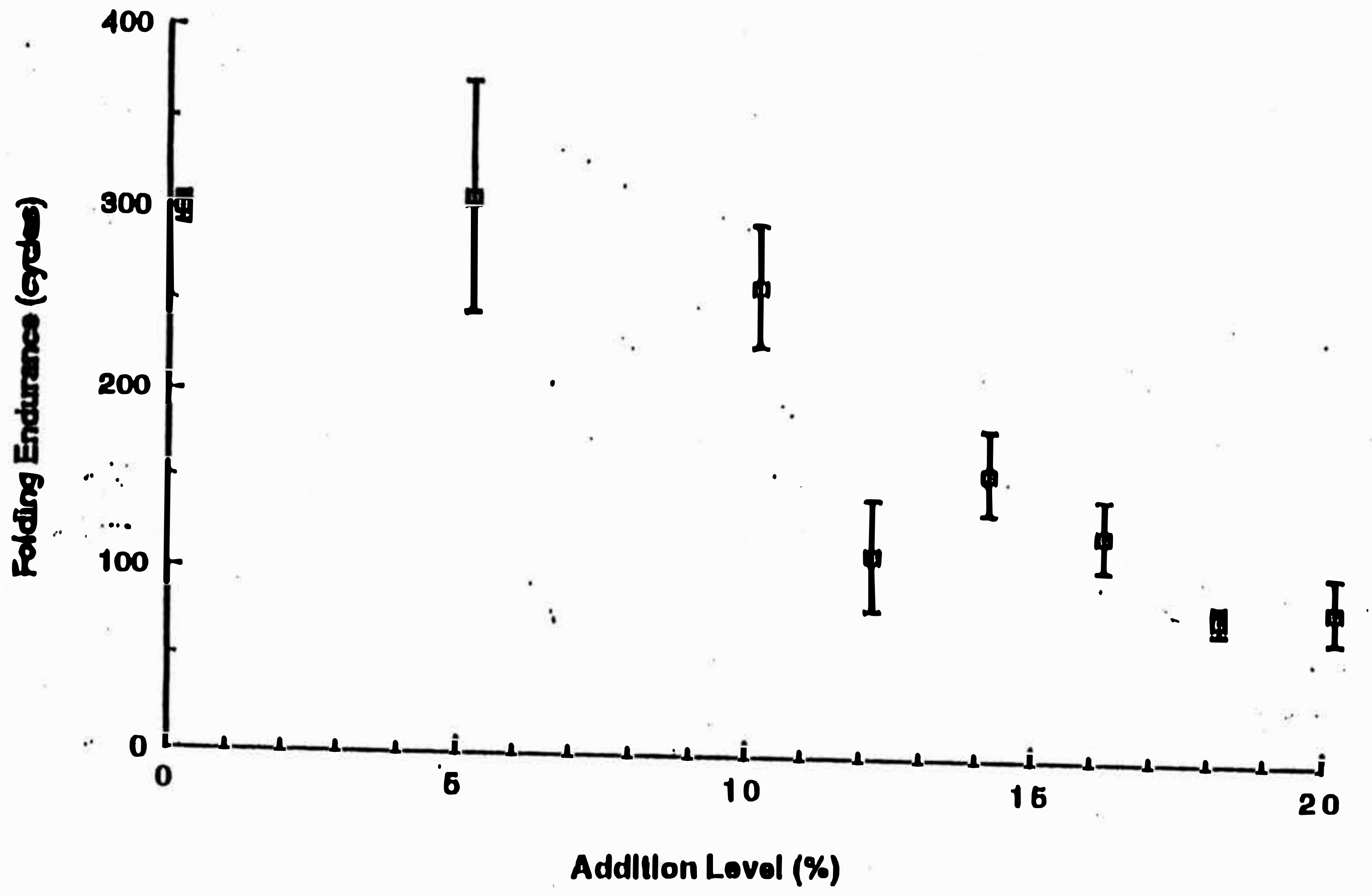
Tensile Index = 653.8 * Force to Break 15 mm Strip / grammage

= Nm/g

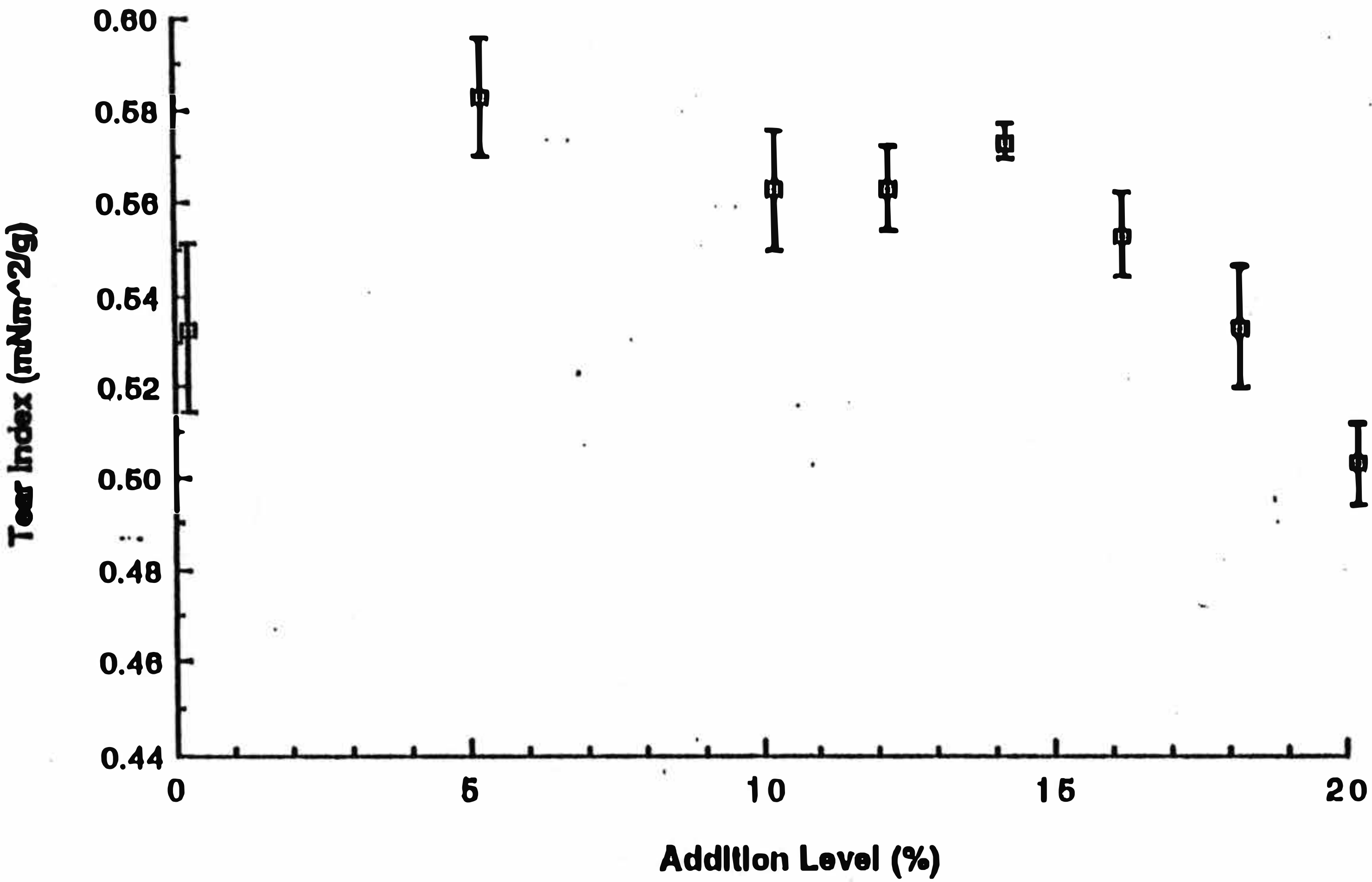
APPENDIX V

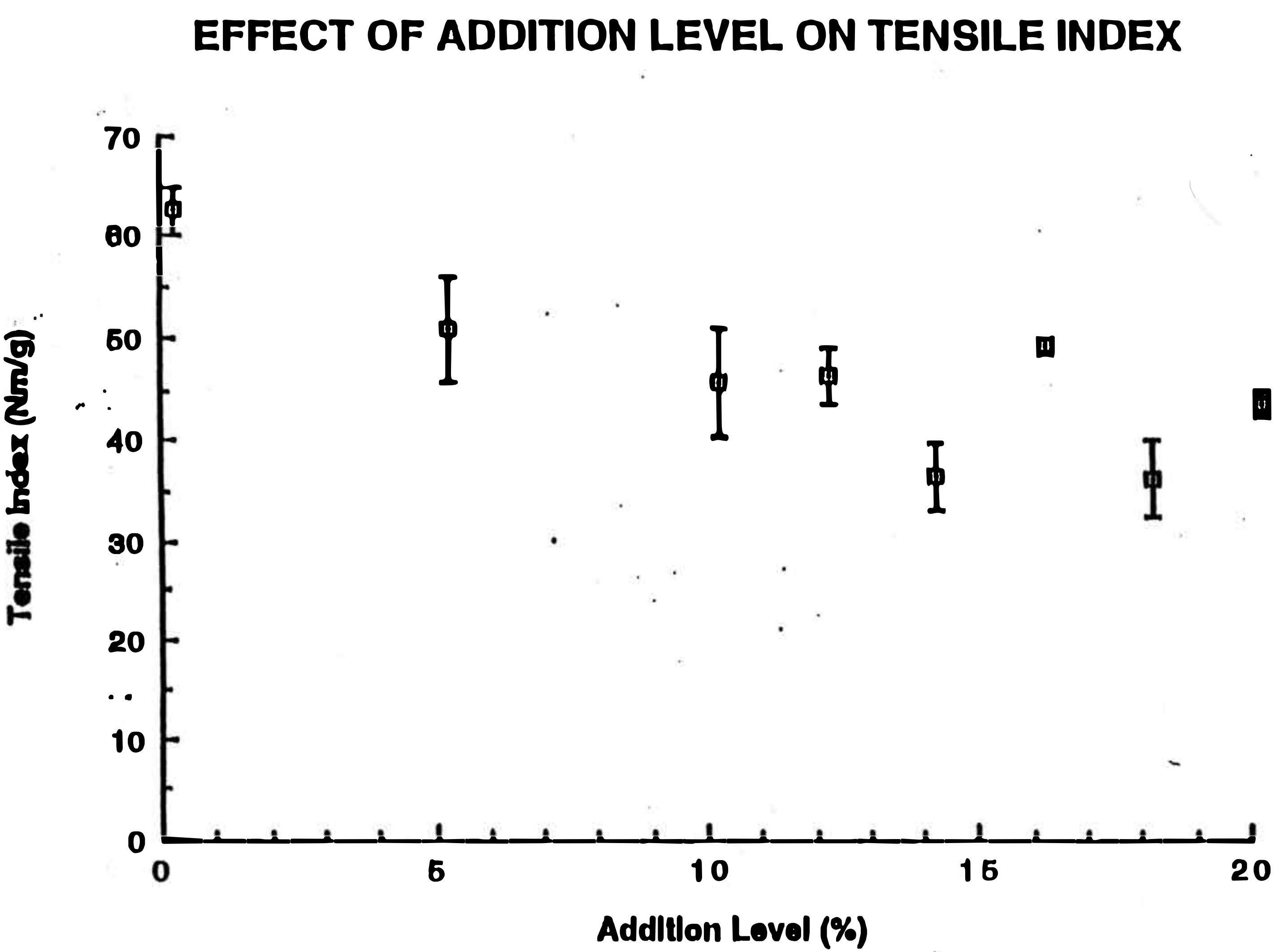
GRAPHS OF RESULTS

EFFECT OF ADDITON LEVEL ON FOLDING ENDURANCE

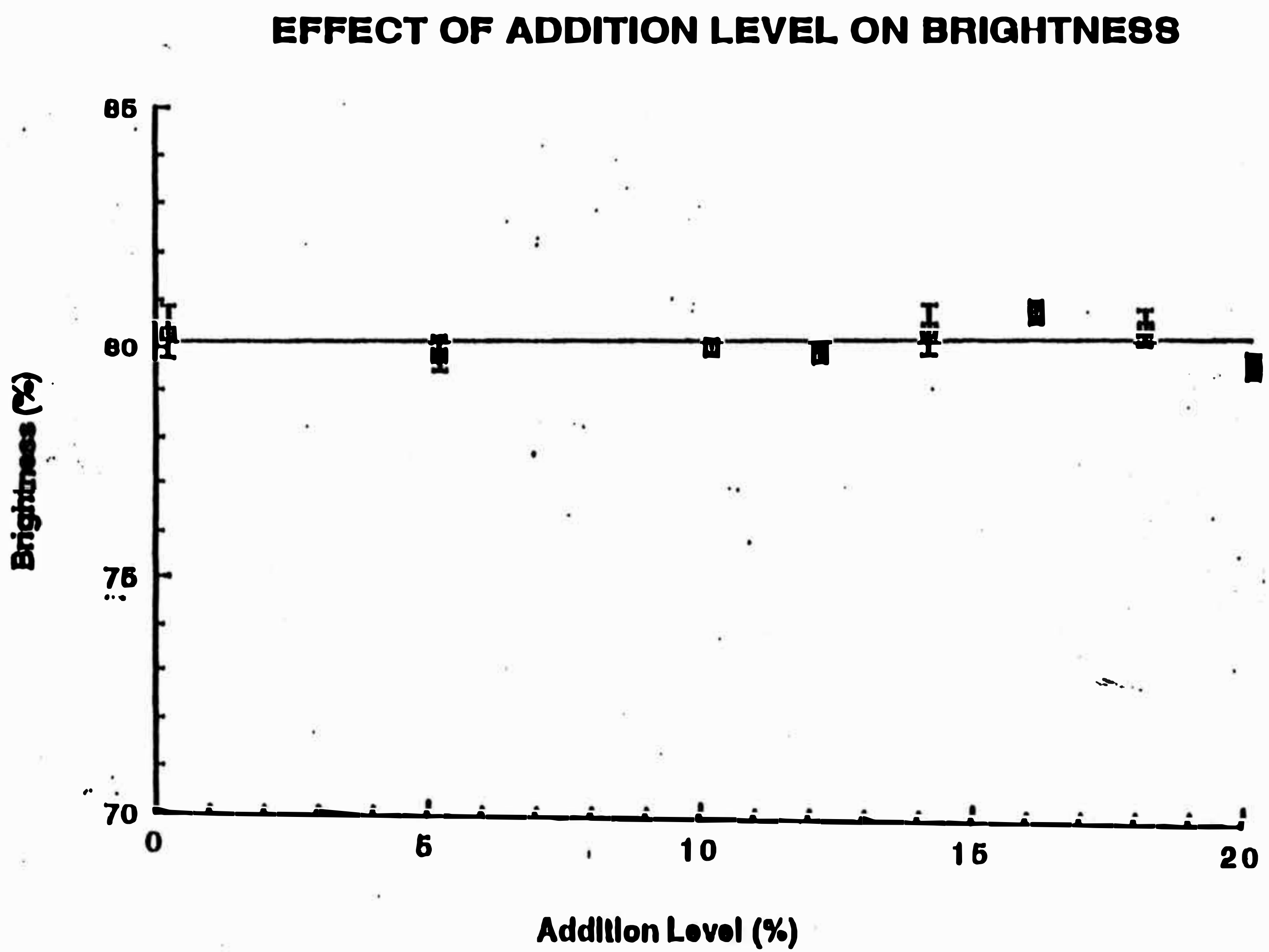


EFFECT OF ADDITION LEVEL ON TEAR INDEX





EFFECT OF ADDITION LEVEL ON TENSILE INDEX
Tensile Index (Nm/g)
70
60
50
40
30
20
10
0
0
5
10
15
20
Addition Level (%)


EFFECT OF ADDITION LEVEL ON BRIGHTNESS
Brightness (%)
85
80
75
70
0
5
10
15
20
Addition Level (%)

APPENDIX VI

COST ANALYSIS

Sidehill Capital Cost	\$9000
Pump Capital Cost	\$7000
Pump Operating Cost	\$1800
Total	\$17800 for the first year
Landfill Disposal Cost	\$60 / ton

(\$60/ton)*(20% of total sludge is recoverable fiber)*
(x tons of sludge) = \$17800

x = 1483 tons of sludge must be screened in the first year to pay for the sidehill screen and pumping requirements, not including depreciation or maintenance