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Different grades of wastepaper such as white blank news (Grade A), computer printout (Grade B), magazine (Grade C), old newsprint (Grade D) and packaging paper (Grade E) were recycled and the effect of recycling on pulp yield, fibre length, tensile strength, tear resistance, modulus of elasticity, stretch were investigated. The morphological and physical properties of fibres were affected by recycling and there were significant reduction in the physical properties of the recycled paper. Based on the findings of this investigation, Grade D and E handsheets were of better qualities for recycling back to marketable paper products.

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Abstract

Different grades of wastepaper such as white blank news (Grade A), computer printout (Grade B), magazine (Grade C), old newsprint (Grade D) and packaging paper (Grade E) were recycled and the effect of recycling on pulp yield, fibre length, tensile strength, tear resistance, modulus of elasticity, stretch were investigated. The morphological and physical properties of fibres were affected by recycling and there were significant reduction in the physical properties of the recycled paper. Based on the findings of this investigation, Grade D and E handsheets were of better qualities for recycling back to marketable paper products.

***Keywords*:** Wastepaper, recycled papers, handsheets, tensile strength, fibre lengths.

RESULTS AND DISCUSSION

Figure 1 shows the fibre lengths of Grade A. The history of the wastepapers used was unknown as well as the number of times recycled prior to the experiment. Since we know that recycling is a destructive process, we expected to have shorter or damaged fibres. Due to damage done to the fibres, the strengths of the handsheets were poor.

After difibering, the recovered pulp was more in grade A with 83.25±0.91% and the lowest yield was recorded for Grade E with 58.76±0.30% (fig. 2). Grade E was observed to have a hardening agent, fillers, which are commonly added to increase the physical properties of packaging papers. It is believed that the fillers accounted for the loss recorded in Grade E because the fillers had to be removed by flocculation after difibering.

Fig. 1: *Slide showing the fibre lengths of recycled pulp of Grade A*

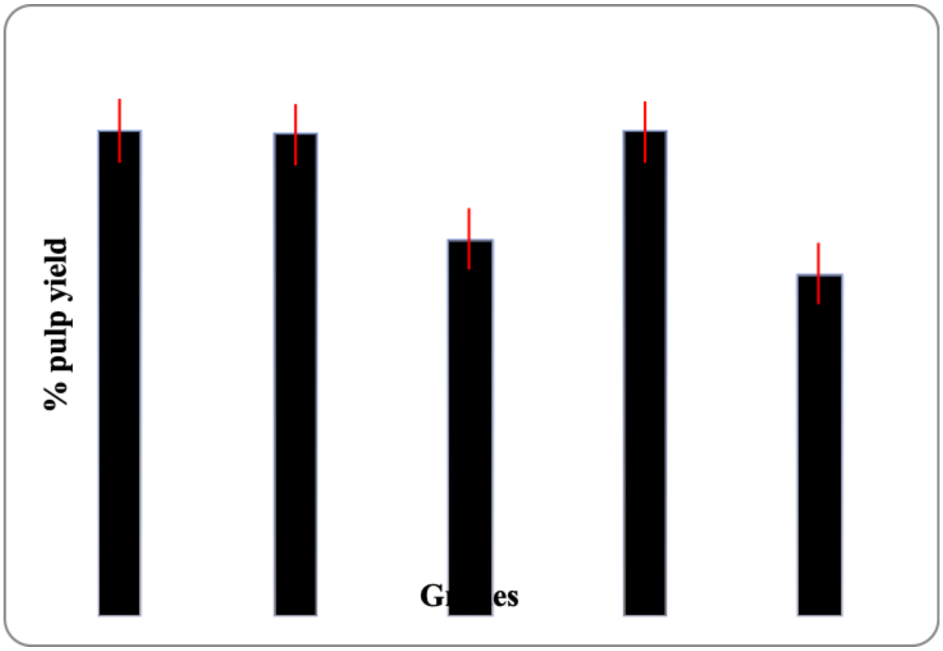

Fig. 2: *Graphical representation of pulp yield denoted with standard error bar.*

It was found that the recycled papers showed lower strength in term of tensile strength, tear, elasticity, and stretch (Table 1). These findings corroborate with other previous researchers that found that mechanical pulps showed complete different responses to recycling [1]. This confirmed that recycling of mechanically pulped paper showed higher strength when compared to chemically pulped paper. Since the pulping process used for the wastepapers was unknown, it was expected to have non-linear results.

Table 1: *Experimental values for all the recycled wastepapers*

Grade	Maximum load	Time of maximum load	Tensile strength	Tear resistance	Modulus of elasticity	Stretch
A	34.17 ± 0.02^{c}	3.90 ± 0.04^{b}	2.59 ± 0.39^{a}	2.32 ± 1.05^{a}	1.58 ± 0.03^{a}	1.06 ± 0.02^{a}
B	22.38 ± 0.52^{b}	4.15 ± 0.08^{b}	4.15 ± 0.14^{c}	2.53 ± 0.12^{a}	2.40 ± 0.02^{b}	1.07 ± 0.04^{a}
C	19.48 ± 1.09^{a}	2.95 ± 0.03^{a}	3.25 ± 0.08^{b}	1.99 ± 0.11^{a}	2.64 ± 0.04^{c}	1.07 ± 0.04^{a}
D	106.55 ± 0.44^{e}	6.90 ± 0.28^{d}	16.14 ± 0.06^{e}	8.75 ± 0.18^{c}	5.62 ± 0.08^{e}	1.69 ± 0.01^{b}
E	72.34 ± 0.04^{d}	6.25 ± 0.21^{c}	7.53 ± 0.05^{d}	6.03 ± 0.07^{b}	2.89 ± 0.06^{d}	1.98 ± 0.04^{c}

Mean±SD followed by the same superscripts in columns are not significantly different ($p<0.05$)

Handsheets from Grade D (16.14±0.06 N/mm^2) and Grade E (7.53±0.05 N/mm^2) showed higher tensile strength when compared to handsheets from Grade A (2.59±0.39 N/mm^2), Grade B (4.15±0.14 N/mm^2) and Grade C (3.25±0.03 N/mm^2) as shown in Figure 2. It has been confirmed that old newsprint and packaging papers are mostly made by mechanical processes [2]. The poor strength exhibited by Grade A handsheets (2.59±0.39 N/mm^2) when compared to Grade B (4.15±0.14 N/mm^2) and Grade C (3.25±0.08 N/mm^2) handsheets could be as a result of the pulping temperature. It was found that the loss of tensile strength of recycled paper could be affected by higher temperatures [3].

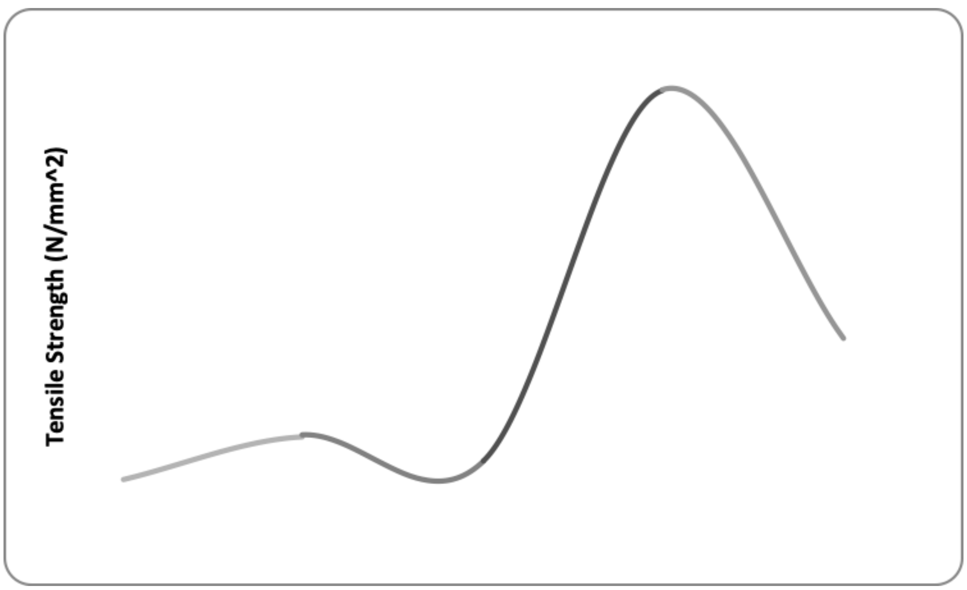

Figure 2: Tensile strength of the recycled handsheets.

Fig. 3 below also shows the effect of recycling on tear strength. During recycling of Grade E (6.03±0.07 N/mm^2) wastepaper, the fillers were not removed completely which in turn impact high tear strength into the sample. Also, Grade D handsheets (8.75±0.18 N/mm^2**)** have very good tear strength. This behaviour is similar to the previous findings of Phipps [4] which predicts modest strength losses for newsprint even at recycling levels of 80%. The tear strength values of Grade A, B and C were not significantly different ($p<0.05$).

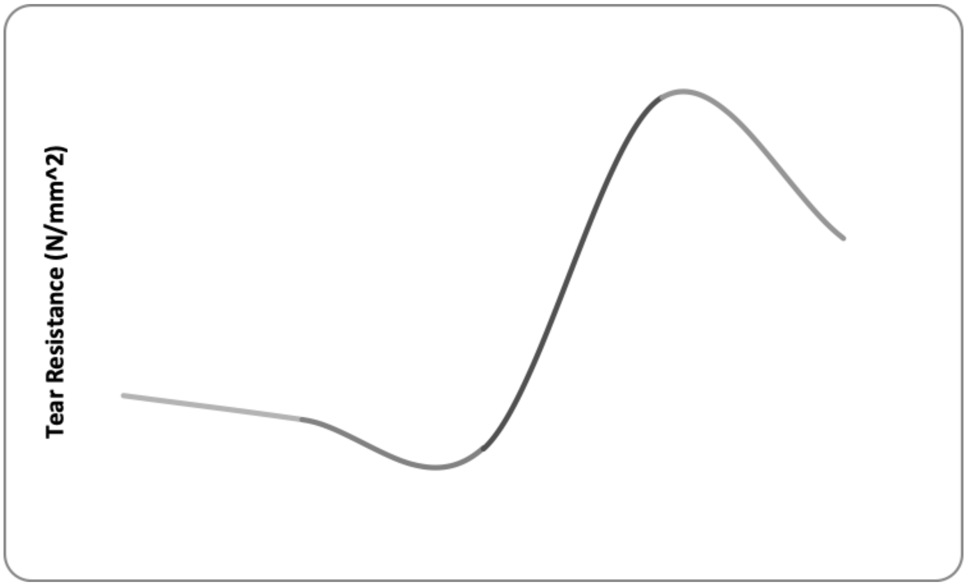

Figure 3: Tear resistance of different grades of wastepaper after recycling

Likewise, the stretch of Grade E (1.98±0.04%) is higher than Grade D (1.69±0.01%) whereas the mean values of Grade A, B and C were not significantly different ($p<0.05$) as seen in fig. 4.

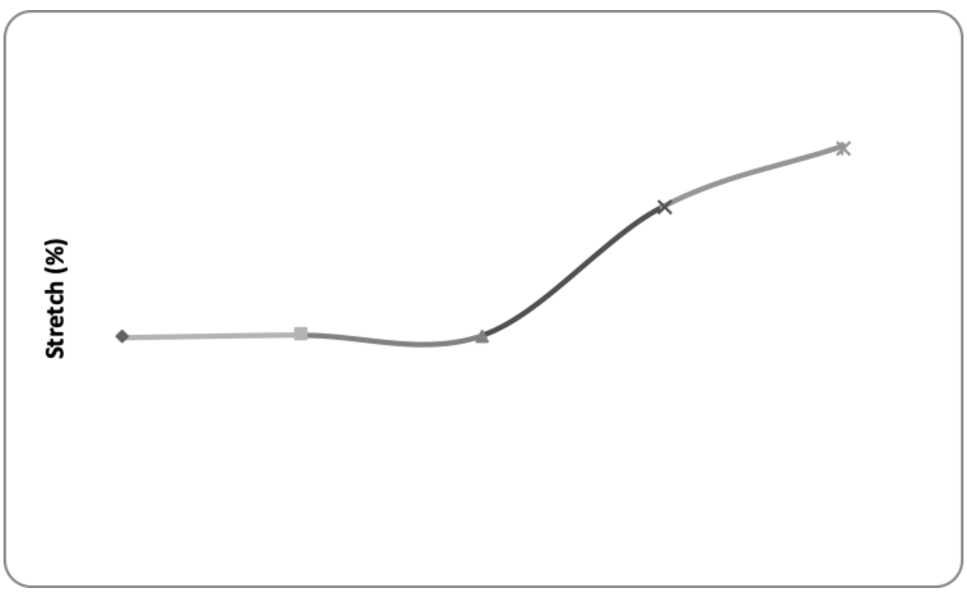

Figure 4: Stretch of the handsheets made from recycling of wastepapers.

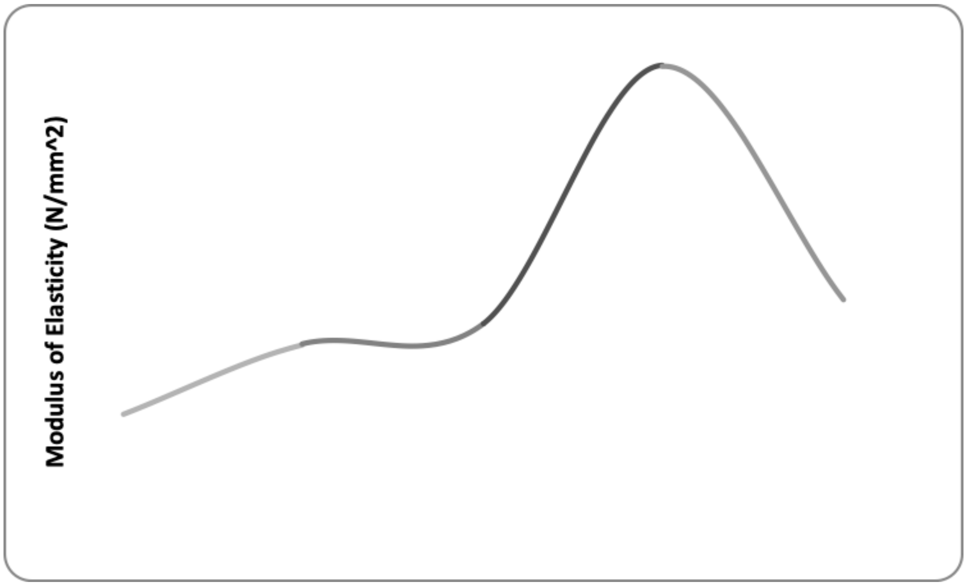

Figure 5: The modulus of Elasticity of the recycled handsheets

Modulus of elasticity which is a measure of paper stiffness is higher for Grade D handsheets (5.62±0.08 N/mm^2). The cell walls of mechanical fibres are not extensively delaminated in the wet state; therefore, hornification is limited during drying and thus has little effect on the subsequent fibre-fibre bonding. The relatively stiff, uncollapsed fibres of mechanical pulps tend to become flatter and more flexible after each successive papermaking and reslushing cycle [5]. These changes tend to increase the relative bonded area and form a thinner, denser sheet. As presented in figure 5, the modulus of elasticity of Grade A (1.58±0.03 N/mm^2), Grade B (2.40±0.02 N/mm^2), Grade C (2.64±0.04 N/mm^2) and Grade E (2.90±0.03 N/mm^2) handsheets were all significantly different ($p>0.05$).

A good paper especially packaging papers must be able to withstand high load for a long period of time. This parameter is mostly considered when making packaging papers. In figure 6, Grade D handsheets (106.55±0.44 N) withstood high load for a long period of time even higher than Grade E handsheets (72.34±0.04 N). Grade C handsheets (19.48±1.09 N) show poor ability to withstand little load. Handsheets with higher tensile strength withstood high load for a long period of time, except for Grade A (34.17±0.02 N) and Grade C (19.48±1.09 N) handsheets as shown in figure 6.

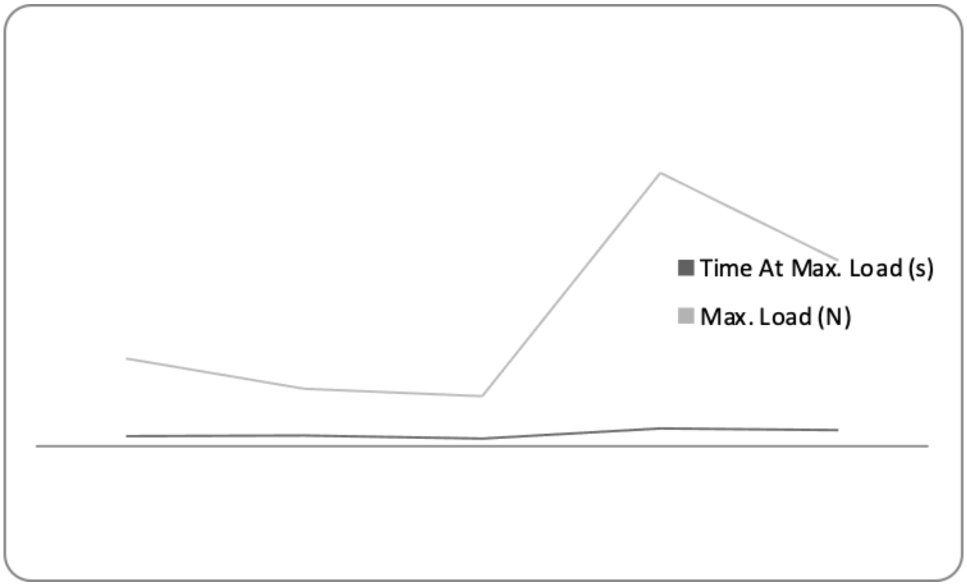

Figure 6: Time versus Maximum load of the recycled handsheets

EXPERIMENTAL

Materials: Hydrogen peroxide (50% vol./vol.), sodium hydroxide (95.0% purity), sodium bicarbonate, sodium silicate were all purchased from an authorised dealer.

Methods: Different grade of wastepapers (Grade A-White Blank Newsprints, Grade B-Computer Print-out, Grade C-Magazine, Grade D-Old Newsprint, and Grade E-Packaging Paper) were sourced from administrative offices and graded according to the outlined specifications by The Institute of Scrap Recycling Industries (ISRI, 1998). They were subsequently deinked, pulped and defibred using domestic blender as a disintegrator according to SCAN M2:64. Direct action of the blender knives, as well as the action of water whirl produced by the rotation of knives, were the defibering agents. In order to minimize the destructive action of the knives, the defibering process was done for just 30 seconds. Each of the grade slurry was collected and subjected to fibre analysis using Visopar Microscope. The disintegrated pulps were made into handsheets and tested using Instron Electromechanical Testing System Model 3369.

Statistical analysis: All the experiments were carried out three times in order to determine the variability of the results and to assess the experimental errors. In this way, the arithmetical averages and the standard deviations were calculated using SPSS windows 16 version.

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