Recycling Mimeograph-Printed Newsprint Paper

E. L. MARI*, A. S. TORRES, C. O. AUSTRIA AND A. B. P. RAMOS

Forest Products Research and Development Institute

Department of Science and Technology,

College, Laguna 4030, Philliphines

Virgin newsprint paper from thermo-mechanical pulp was subjected to a laboratory recycling scheme, which involved mimeograph-printing, re-pulping, de-inking, washing, refining, and handsheet-forming, without adding other fibre in between cycles. Fibre dimension, pulp freeness and paper properties were determined after each cycle until the fifth, at which about 20% of the original material remained. The remaining fibre was then mixed with virgin pulp, the original newsprint and unsorted mixed office waste to determine the proportion necessary for acceptable properties.

The results indicated remarkable modification in distribution of fibre properties, a decreasing amount of long fibre with corresponding increase of short fibre in the course of recycling and loss of fibre. Refining generally improved the strength properties of paper from recycled fibre.

About 20 % to 30 % of either thermo-mechanical pulp or unsorted mixed office waste was found sufficient for blending with recycled fibre to obtain acceptable strength properties.

Key words: tmp newsprint, handsheet, number of recycling, paper properties

History says that papermaking actually started in China about 2000 years ago from recycled waste material of rotten fishnets. Later, recycling of fibre or waste paper was also developed. Proof of its development as early as the 14th century can be found in Venice, Italy.

There are many benefits claimed from recycling paper, namely, (Manfred 1985) preserves forests — approximately seventeen trees are saved for every ton of paper recycled; (2) conserves water — recycled paper uses 55% less water in its manufacture than new paper; (3) reduces water pollution by 35%, reduces air pollution by 74% and eliminates many toxic pollutants; (4) saves more than 3.3 cubic yards of landfill space per ton of recycled paper and (5) saves 60% – 70 % of energy used for virgin pulp (CencalRecycling, 2011).

Recycling of papers, admittedly, is beneficial in several aspects and the process continues to be developed as research continues on what happens to the fibre as it undergoes recycling. A review of literature by Howard (Sutjipto *et al.* 2008) illustrated that recycled pulp quality and recycled paper properties depended only partly on the recycling process itself but rested mainly on the ‘history’ of the material being recycled and on the processes and treatments experienced by the material during papermaking, converting and use. Chemical pulp, unrefined chemical pulp, and mechanical pulp appear to behave differently during recycling. Although extensive research has led to the identification of many of the effects of the relevant factors, the review concluded that there were still gaps to be worked on to understand the implications of using higher levels of recycled fibre.

* Corresponding author (e-mail: mari_erlinda@yahoo.com)

A recent study dealt on the effect of recycling on properties of paper from different sources of pulp (Howard 1993). Reports on recycling, however, have dealt mainly on re-slushing, refining and handsheet-forming, and hardly include the actual printing on the material being recycled. This particular paper reports a recycling scheme using virgin newsprint paper and a mimeographing machine for printing. Mimeographs are well-known duplicating machines used in schools and offices for the reproduction of instructional material and office forms. The recycling was also planned such that no other fibre was added in-between cycles until the fifth cycle.

The study was conducted to determine (1) the changes in the properties of virgin newsprint paper and its fibre due to recycling and (2) the effects of blending the recycled fibre with virgin pulp, mixed office waste or virgin newsprint paper.

MATERIAL AND METHODS

Material

The main material used was virgin newsprint paper from thermo-mechanical pulp (TMPN)

obtained from Norway. Virgin pulp (TMP) was also requested for the blending experiment. Unsorted mixed office waste paper (UMOW), also used in the blending experiment, was collected from the FPRDI offices.

The ink used for printing was ordinary mimeographing black ink. The chemicals used for deinking and the corresponding levels of addition were as follows (Basis: ODW pulp):

Chemicals	Charge (%)
Sodium hydroxide	1
Hydrogen peroxide	1
Dispersant	1
Foamer/collector	3
Sodium silicate	1
DTPA (Diethylenetriamine pentaacetic acid)	0.2

METHODS

Recycling Process

One recycling cycle involved printing, disintegration or re-pulping, de-inking and flotation, washing, refining, and handsheet forming (Figure 1). No other fibre were added in-between cycles until the fifth cycle.

Figure 1. Laboratory recycling scheme.

The raw material TMPN was used as a printing substrate for mimeographing. The printed raw material was then manually shredded and repulped initially in the laboratory disintegrator at a 4% consistency level (using water at 45°C – 50°C) for 4 min. The repulping/de-inking chemicals were then introduced into the slurry for a total retention time of 15 min. The pH of the slurry was within 10.7 – 11.5. The slurry was then transferred into the flotation cell. The consistency was lowered to 1% by adding water. Compressed air was introduced into the cell. This generated bubbles in the slurry, which carried the ink particles after being skimmed off the cell. This stage was done within 10 min. The pulp was then washed thoroughly with tap water at pH 6 – 7 with the aid of a screened-bottom box. The freeness of the pulp was measured and when the value was greater than 230 ml, the pulp was subjected to refining. Sample pulp was then taken for fibre fractionation and fibre measurement. The rest of the pulp was formed into handsheets. Representative handsheets were then tested while all the others were subjected to further recycling. The cycle was continued until the fifth stage when there was only about 20% of the raw material left.

The material TMPN is a machine-made paper whose properties differ from handsheets. To be consistent with the make of paper, a separate portion of the original TMPN was, therefore, disintegrated and handsheets (TMPN #0) were prepared from it for use as reference material.

Measurement of Fibre Dimension and Pulp Freeness

Fibre length distribution was measured by the fractionation method using Bauer McNett Classifier (TAPPI Standard T234) (TAPPI). The fractionation method measures the average fibre length and length distribution directly by weight, with the aid of a fibre fractionator, which is a series of successive screens of

decreasing mesh size (Mesh 14, 24, 48 and 100). The fraction for Pass Mesh 100 was calculated as the difference of these fractions from 100.

Fibre length was measured using a microscope (TAPPI Standard T232) (TAPPI). The microscope method consists of examining a slide of fibre under a microscope and measuring the length of every fibre.

Pulp freeness, which indicates the ease with which water drains away from the papermaking fibre, was determined following the TAPPI Standard T227 (TAPPI).

Determination of Handsheet Properties

Using the standard laboratory sheet former, handsheets with a basic weight of 43.5 g/m² were formed from the deinked pulp following that of the original material (TMPN). These were conditioned in the standard paper conditioning and testing room for at least four hours. Tests for burst, tear, and tensile strength properties were conducted according to the TAPPI Standards (TAPPI) T403 ts-63, T414 ts-64, T220 os-71, respectively.

Blending of Recycled TMPN with Virgin TMP, TMPN, or Unsorted Mixed Office Waste Paper

Using the proportions listed below, recycled pulp (TMPN #5) was mixed with TMP, TMPN #0, or UMOW; then handsheets were formed and tested:

Blends	Proportions
TMPN #5: TMP	= 90:10, 80:20, 70:30
TMPN #5: TMPN	= 90:10, 80:20, 70:30
TMPN #5: UMOW	= 90:10, 80:20, 70:30

Statistical Analysis of Data

The effects of number of recyclings and blending of fibre on the properties of the fibres and handsheets were evaluated statistically using

analysis of variance (ANOVA) in completely randomized design (CRD) and Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Properties of Virgin TMPN and Its Handsheets

It was expected that the machine-made TMPN would differ in properties from the handsheets made from re-slushing it due to differences in orientation of the fibre and several other factors. Table 1 shows these differences. The burst index readily lost about 40% of its original value (1.47 kPa.m²/g). The lower burst index value of TMPN #0 might be due to the hornification of the fibre resulting from drying of the TMPN. This meant that the penetrability of hemicellulose to water had decreased. In this condition, the fibre did not have good contact with each other during consolidation of the sheet.

The higher values of tear and tensile indices, and folding endurance of TMPN # 0, the machine-made TMPN taken at the cross direction (CD), had to do with the orientation of fibre. The machine-made TMPN had short fibre concentrated in the CD and long fibre in the MD while the laboratory handsheet TMPN #0 consisted of uniformly distributed long and short fibre. Tear strength is dependent on the length of the fibre; the longer the bonded fibre, the harder is it for the paper to tear. There was a need for more force to be applied before the fibre broke due to the longer length. Similarly, the tensile strength and folding endurance of TMPN #0 might have benefited from the

random formation of bonds between short fibre, and short fibre with long fibre.

The TMPN #0 values were used as reference for evaluating the effects and the critical level of recycling.

Effects of Recycling on Pulp/fibre Characteristics

Papermaking involves a series of unit operations which cause corresponding impact on fibre properties and consequently on paper properties. Thus, studies may be specifically on the impact of each operation or the impact of a collection of unit operations (Ellis & Sedlachek 1993).

This particular laboratory study attempted to produce paper from fibre after recyclings, done up to five times. Each recycling involved printing by mimeographing, re-pulping, deinking using a flotation cell followed by washing, refining, and handsheet-forming. The collective effect of the recycling process was evaluated based on the properties of the handsheets formed while the impact of each operation was traced to the fibre distribution and dimensions of the data.

Figure 2 shows the mesh fractions of TMPN before and after recycling. The longest fibre in Mesh #14 decreased continually with each recycling while the other fractions fluctuated. The greatest decrease (from 36.1 % to 14.99 %) or about 58%, was right after the first recycling. By the second cycle, the amount of fibre in Mesh #14 had been reduced by about 88 %. At the fifth cycle (TMPN #5), Mesh #14's long fibre

Table 1. Properties of TMPN and its handsheets.

Material	Freeness CSF (ml)	Basis weight (g/m ²)	Burst index (kPa.m ² /g)	Tear index (mN.m ² /g)	Tensile index (N.m/g)	Folding endurance
TMPN (MD)	193	43.48	1.47	4.04	48.07	38
(CD)				6.32	17.02	3
TMPN #0	193	42.46	0.88	8.13	27.64	5.09

Figure 2. Percentage of each mesh fraction of TMPN fibre before and after recycling.

was virtually gone. The resulting increases in the other fractions due to breaking of the longer fibres were greatest with Mesh #48. Fibre passing the Mesh #100 screen were usually lost in the washing stage. Thus, starting from 1200 g of the original TMPN, the remaining material at the fifth stage was only about 200 g. Fibre fractionation data, therefore, gave an indication of the presence or absence of the long fibre in a certain material. This change in distribution of fibre properties was usually an impact due to screening, cleaning and flotation cells in the de-inking process (Ellis & Sedlachek 1993).

Table 2 shows the freeness of the pulp and the length of the fibre for each mesh fraction of TMPN before and after recycling. The pulp was refined to obtain freeness within a range not too far from the original material. In this case, the freeness range was targeted within 193ml – 230 ml. Thus, refining was not conducted in the first and fourth cycles.

Fibre length refers to the average length of the fibre and indicates how long or short the fibre is. These are important basis of information in evaluating the quality of the wastepaper intended for recycling.

Fibre were randomly selected and carefully noted as either of full length or of broken fibre. The amount of broken fibre ranged from 40 % to 80 %. Each material exhibited a decreasing trend in the length of fibre, whether full length or broken, with increasing mesh size. Each recycling generally caused a further decrease in fibre length of all mesh fractions. Modification of fibre dimensions were said to be effects of refining and dispersion (Ellis & Sedlachek 1993).

Effects of Recycling on Paper Properties

The effects of recycling on the properties of the handsheets are summarized in Table 3, which shows the treatment means for each property, after conducting tests for correlation with density, ANOVA and DMRT on the data.

Burst strength significantly decreased in the third cycle when much of the long fibre had been lost in the previous cycles. In the fourth cycle, burst strength decreased further as the fibre was not conditioned by refining. The burst index value recovered with refining in the fifth stage due possibly to fibrillation of fibre which may have increased the numbers of bonds of fibre and fibrils.

Table 2. Freeness and fibre length of TMPN before and after recycling.

Material	Freeness CSF (ml)		Mesh	Fibre length (mm)			
	Initial	Final		Full	Broken	Average	% Broken
TMPN #0	193	No refining	14	3.0610	2.361	2.7812	40
			28	2.5982	1.7885	2.1432	56
			48	2.2610	1.4686	1.8172	56
			100	1.1109	0.9000	0.9932	56
TMPN #1	217	No refining	14	2.9710	2.1364	2.6040	44
			28	2.6325	1.8640	2.2328	52
			48	2.5236	1.3409	2.0032	44
			100	1.8570	1.2747	1.5076	60
TMPN #2	410	Refined to 202	14	2.8130	2.1760	2.5580	40
			28	2.4936	1.8486	2.1324	56
			48	2.0478	1.1864	1.6688	44
			100 ^a	—	—	—	—
TMPN #3	468	Refined to 200	14	2.240	1.8700	2.0624	48
			28	1.8431	1.4608	1.6596	56
			48	1.7814	1.1561	1.3312	72
			100	1.1820	0.6840	0.7836	80
TMPN #4	230	No refining	14	2.4500	1.5400	1.9412	56
			28	2.2418	1.4829	1.8168	56
			48	2.1000	1.0227	1.4536	60
			100	1.3390	0.8080	1.0204	60
TMPN #5	259	Refined to 211	14	2.2400	1.3880	1.8992	40
			28	1.4527	1.1586	1.2880	56
			48	1.2264	1.0628	1.1348	56
			100	0.7680	0.6340	0.6876	60

^a Sample was inadvertently lost in handling.

Table 3. DMRT on the treatment means for each property of handsheets from TMPN and recycled TMPN.

Treatment (Number of recycling)	Freeness CSF (ml)	Burst index (kPa.m ² /g)	Tear index (mN. m ² /g)	Tensile index (N.m/g)	Folding endurance
TMPN 0	193	0.876 AB	8.128 B	27.643 A	5.090 A
TMPN 1	217	1.080 A	10.282 A	22.149 BC	6.163 A
TMPN 2	202	1.018 A	5.740 C	21.433 BC	1.623 B
TMPN 3	200	0.754 B	7.344 B	22.555 ABC	1.342 B
TMPN 4	230	0.682 B	10.192 A	20.085 C	1.378 B
TMPN 5	211	0.912 AB	7.500 B	25.474 AB	1.055 B

Means (in each column) followed by the same letter are not significantly different from each other.

Tear strength values at the first and fourth recyclings, where refining was not conducted, were higher than where refining was done and were even higher than in the original material. It is generally recognized that fibre length directly affects tear strength. Cross-reference with fibre length data in Table 2, however, showed a consistent decrease in values with every recycling. Thus, the high tear strength values at the first and fourth stages might have been due to factors other than fibre length. The original material used in this experiment was made from thermomechanical pulp (TMP). It has been reported that papers from TMP do not really show any significant change in tear strength with recycling (Chatterjee *et al.* 1993).

Tensile strength (measured as breaking length) has been reported to decrease the most after the first and second recycling, then on gradually in the succeeding recyclings (Ellis & Sedlachek 1993). In this experiment, the greatest decrease in tensile strength was after the first cycle. Succeeding cycles no longer caused a significant decrease in values compared with the first, indicating the positive effect of refining. Increase in bonding was said to be the main reason for the rise in paper tensile strength due to pulp beating or refining (Dasgupta 1994). The leap back in the fifth stage to almost the original value was rather unexpected. At this stage, there was almost no more long (Mesh 14) fibre (Figure 1 and Table 2). The compaction of the remaining shorter (Mesh 28 to 100) fibre probably resulted in an increase in the number of bonds and thus this effect was achieved.

In the case of folding endurance, there was no significant decrease in value after the first stage. The drastic decrease manifested from the second recycling indicated the brittleness of the paper and the washing out from the paper of chemicals that had been used for the original TMPN.

Based on the above data, the critical level of recycling might be at the fifth stage except for

folding endurance. However, there would be a need also for a greater input of virgin or better quality fibre because refining also increases the volume of fibre which ultimately goes down the drain during the washing stage.

Effects of Blending Recycled Fibre with Virgin Fibre or Mixed Office Wastes

Recycled paper is actually the product of a mixture of different qualities of fibre. It may be composed of virgin pulp and recycled fibre from first, second, and or other stages.

This particular experiment was aimed to evaluate the properties of handsheets from mixtures of the preceding experiment's fifth stage recycled fibre (TMPN #5) with virgin pulp (TMP), with the original material TMPN, or with unsorted mixed office waste (UMOW). The material were disintegrated and simply mixed together. Table 4 summarizes the data obtained for this experiment after conducting ANOVA and DMRT.

The pulp blends showed no necessity for refining as the freeness values were within the desired range of 193 ml – 230 ml.

For burst index, each value was significantly different from the others. Although the highest value was obtained from the pulp blends with the greatest amount of virgin fibre (70 TMPN #5: 30 TMP), blending with UMOW generally performed better than blending with TMP or TMPN #0. Inconsistency in trend were observed with blends having 30% of either TMP or UMOW.

Tear and tensile indices were not significantly affected by pulp blend. This meant that the values did not differ significantly from each other. Compared with 100 TMPN #0, the tear index value was much higher than that of any of the treatment means. This indicated that blending recycled fibre with up to 30% of virgin fibre or UMOW could not compensate

Table 4. DMRT on the treatment means for each property of handsheets from recycled TMPN blended with unrecycled TMPN, UMOW, or TMP.

Treatment (Pulp blends)	Freeness CSF (ml)	Burst index (kPa.m ² /g)	Tear index (mN. m ² /g)	Tensile index (N.m/g)	Folding endurance
TMPN 0	193	0.88	8.128	30.086	4.566
TMPN#5:TMPN#0					
90 : 10	202	0.65 G	4.02	25.78	1.49 C
80 : 20	193	0.77 EF	4.39	26.56	2.38 BC
70 : 30	211	0.72 FG	5.00	27.31	2.13 C
TMPN#5:UMOW					
90 : 10	220	1.12 BC	4.45	31.21	1.96 C
80 : 20	211	1.17 AB	4.33 A	28.12 A	3.77 A
70 : 30	220	0.74 FG	3.95	27.77	2.45 BC
TMPN#5: TMP					
90 : 10	193	0.89 DE	4.16	25.63	2.04 C
80 : 20	208	0.99 CD	4.42	28.32	2.36 BC
70 : 30	189	1.28 A	4.40	29.03	3.18 AB
TMPN# 5	211	0.912	7.50	25.474	1.055

Means (in each column) followed by the same letter are not significantly different from each other.

for the deleterious effect of recycling. Although the original value of the tensile index was higher than most of the treatment means, the difference was not significant. This justified the practice of blending recycled fibre with virgin or other better quality fibre. Folding endurance values likewise showed the beneficial effect of blending recycled fibre with other fibre. Much improvement was observed with a 20% to 30% % proportion of either TMP or UMOW. Even with only 10% of TMP or UMOW, the folding endurance had almost doubled.

CONCLUSION AND RECOMMENDATIONS

- A remarkable modification in fibre properties, from the original TMPN in every cycle of the recycling process, was observed. While refining was known to shorten the fibre, modification in distribution of fibre properties was attributed to the de-inking process.

- Recycling with refining generally shortens the fibre. Thus, the long fibre fraction decreases continually with each recycling while the other fractions increase. In this study, the greatest decrease, about 58%, came right after the first cycle. By the second cycle, the long fibre fraction was only about 12%.
- Refining generally improves the strength properties of paper from recycled fibre. With this recycling scheme, the critical level of recycling lasted up to the fifth stage but with barely 20% of the original material remaining.
- A proportion of about 10% to 30% of either TMP or UMOW was sufficient for the blending with recycled fibre to obtain strength properties within acceptable limits.

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