INFLUENCE OF RECOVERED PAPER QUALITY ON RECYCLED PULP PROPERTIES

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Statistical data show that a further increase of recovered paper (RP) supply to European paper mills could come mainly from increasing and improving household collection. However, it is generally accepted that an extended collection from households is always detrimental to RP quality. The low quality of recovered paper is determined by the high content of unusable materials consisting of non-paper components and unwanted paper and board (paper and board that does not conform to RP grade definition). In this study, the effects of unwanted paper and board (p&b) on recycled pulp properties are analysed for RP grades 1.11 and 1.04, originated from household collection. In the case of deinking RP grade 1.11, it was shown that even a low content (3-5%) of brown packaging p&b strongly affects the optical properties of deinked pulp, by decreasing brightness and by increasing the number and size of specks, due to brown fibre flakes. In the case of packaging RP grade 1.04, the increasing content of graphic paper results in lower freeness, higher ash and short fibre contents and lower mechanical strength of recycled pulp.

Keywords: graphic paper, household collection, packaging paper, recovered paper, recycled pulp

INTRODUCTION

Recovered paper (RP) became a valuable raw material for the paper industry already in the early 20th century. Over the past decades, the recovery and utilization of paper in the paper and board industry has increased throughout the world, and this trend will continue. In Europe, after the success of the first European Declaration on Paper Recycling (2000-2005), a new voluntary commitment of the paper recycling chain was signed for the period 2006-2010, with the challenge of achieving a recycling rate of 66% in 2010.[1] By 2008, this objective was already achieved, making paper one of the most recycled products and Europe – the global champion in paper recycling.[2]

Of course, recycling plays an important part in paper industry sustainability, since it contributes to economic and environmental performance, as well as to public health. From an economic point of view, recovered paper is a very important source of raw fibre material in paper and board industry, accounting for about 50% of total papermaking fibre used at a worldwide level.[3] Recycling of used paper products reduces the environmental impact by decreasing forest and energy use, as well as landfill, but also by minimizing water and air pollution. However, there are many questions about the maximum recycling rate, which could allow the best balance of the three pillars of sustainability – environment, economy and society.

The theoretical limit of paper and board (p&b) recycling rate is around 81%, since 19% of the paper products are not collectable or recyclable for technical reasons.[4] A study performed within the framework of COST Action E48 – Limits of Paper Recycling[5] estimated the maximum limit of p&b recycling rate in Europe to 75%. An increase

of the p&b recycling rate from 66.6 achieved in 2008) to 75% will be progressively more difficult because:

- developed countries with high consumption *per capita* and high environmental consciousness reached a collection rate of 72-74.5%, close to the maximal limit;[6]
- recovered paper quality is deteriorating as the collection rate continues to increase;[7,8]
- all easy sources (industry and trade) have been tapped and an increase in recycling may come from small sources, with high spreading and contamination, mainly from household collection.[9,10]

At a European level, a rough estimation of the different sources indicates that 50% of the recovered paper is collected from industry and trade, 40% from households and 10% from offices,[11] although these percentages can differ greatly among countries, as well as among the collection systems employed. The first sources are well-exploited, being of high quality and easily collectable. Statistical data on the routes of paper and board consumed in CEPI countries have shown the following distribution:[12] 56.3% – recycling in paper mills; 12.0% – RP net trade; 19% – non-collectables and non-recyclables; 12.7% – other recycling/recovery and final disposal. Thus, a further increase of the recovered paper supply for European paper mills could come mainly from "other recycling/recovery and final disposal", by increasing and improving household collection. The Revised Waste Directive created the framework for realizing this objective by setting an obligation to collect recyclables separately and by prioritizing recycling over incineration.[11]

Household collection consists of numerous small sources, which creates pressure on the costs and quality of recovered paper. It is generally accepted that an extended recovered paper collection from household is always detrimental to its quality, and many studies support this conclusion.[13,14] The main product of separate household collection is recovered paper of mixed grades, usually grades 1.01 and 1.02, described in EN 643 as follows:[15]

- *RP grade 1.01*: mixed papers and boards, unsorted, with unusable materials removed; this grade is provided directly by selective collection;
- *RP grade 1.02*: mixed papers and boards of various qualities (sorted) containing a maximum of 40% newspapers and magazines; this grade could come from specific household collection with removal of large contaminants (non-paper materials and non-recyclable p&b), or as a secondary stream from mechanical/automatic sorting of grade 1.01, when grades 1.11 and 1.04 are separated as main streams.

Currently, grades 1.01 and 1.02 contain more than 50% graphic papers (newsprint, magazines and other graphic papers) and an important fraction of packaging paper and board. Both grades are characterized by a high variation of the graphic/packaging ratio, as well as by high non-usable material contents.[16,17]

The low and variable quality of mixed RP grades is translated into sorted grades obtained by different sorting technologies. Studies on the quality of recovered paper grades resulting from household collection sorting (grades 1.11 and 1.04) conclude that, in both cases, there is a trend to increase the content of unusable materials. In the case of grade 1.11, the unusable material consists mainly of non-deinkable paper and board (brown/gray board) while, in the case of grade 1.04, it consists of graphic papers.[18,19,20]

EXPERIMENTAL

Objectives and tasks

Considering the actual trends of recovered paper quality, the objective of this study was to assess the effects of unwanted paper and board on recycled pulp properties. The investigations focused on the two main RP grades from household collection – deinking grade 1.11 and packaging grade 1.04. The derived objectives were:

- to evaluate the influence of graphic paper content on the properties of recycled pulp for packaging paper production;
- to evaluate the influence of packaging paper content on the properties of deinked pulp for newsprint paper production.

Figure 1 presents schematically the main tasks of the experimental program.

Materials

Raw materials

Two types of recovered paper grade were used in the study: unsorted paper and board packaging used for the production of packaging paper (provided by VRANCART SA, Romania);

graphic recovered paper (newsprint and magazines) collected from press dealers.

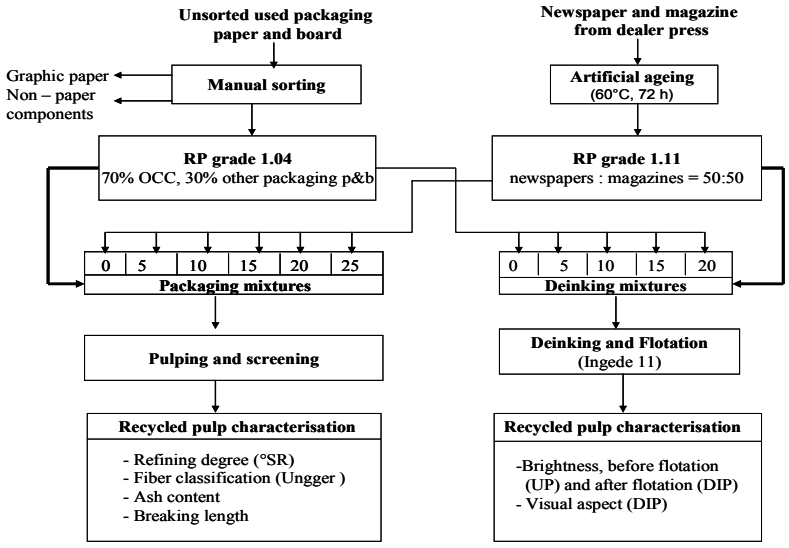

Figure 1: Experimental program

Preparation of recovered paper (RP) grades

In the first stage of the experiment, the collected RP samples were manually sorted, to remove non-paper components, as well as the paper and board not corresponding to the grade definition. The European Standard EN 643 provides the following definitions for the grades here investigated:

RP grade 1.11: sorted graphic paper for deinking from households, newspapers and magazines, each at a minimum of 40%; the percentage of non-deinkable paper and board should be reduced over time to a maximum level of 1.5%; the actual percentage is to be negotiated between buyer and seller;

RP grade 1.04: supermarket corrugated paper and board; used paper and board packaging, containing a minimum of 70% of corrugated board, the rest being solid board and wrapping papers.

The RP grades defined above were prepared in the following way: graphic papers and non-paper components were removed from unsorted packaging paper, for obtaining a mixture of 70% corrugated board and 30% other board and packaging papers (similar to grade 1.04); a mixture of newsprint and magazines at a 1:1 ratio was prepared and an accelerated ageing process was applied (60 °C, 72 h) for obtaining RP grade 1.11.

Preparation of model recovered paper mixtures with different contamination levels

In the next step, after determining the moisture content (packaging samples – 9.31%, graphic paper – 6.45%), model mixtures with various levels of contamination were prepared for each grade:

- model mixtures for deinking RP consist of deinking recovered paper (grade 1.11) mixed with brown packaging recovered paper (grade 1.04) at percentages between 0 and 20%;
- model mixtures for packaging grades consist of packaging recovered paper (grade 1.04) mixed with graphic recovered paper (grade 1.11) at percentages from 0 to 25%.

Methods

Recovered paper processing

The use of recovered paper as a raw material involves a complex multi-stage treatment of the recovered paper, for separating and eliminating the contaminants for finally obtaining recycled pulp. The complexity of the processing system depends on the recovered paper grades used, as well as on the paper grades to be produced. The two cases investigated in this study (RP grade 1.11 for newsprint paper and RP grade 1.04 for packaging paper) involve different processing systems. At a laboratory scale, the following processing systems were used:

RP grade 1.11 (model mixtures with variable content of brown papers): recycled pulp was obtained by alkaline deinking, following the steps and operation parameters described by Ingede Method 11 (pulping chemistry: 0.6% NaOH, 1.8% sodium silicate, 0.7% H_2O_2, 0.8% oleic acid; pulping in Hobart pulper: consistency c = 15%, 20 min, 45 °C, 128 mg/L Ca^{2+}; conditioning in water bath: c = 5%, 45 °C, 60 min; homogenization in a standard disintegrator: c =

4%, 45 °C, 1 min; dilution and flotation with PTS cell: c = 0.8%, 45 °C, 10 min).[21]

RP grade 1.04 (model mixtures with variable content of graphic papers): the recycled pulp stock was obtained by pulping recovered paper in a laboratory pulper at low consistency (3%), subsequently sorted on a slotted vibratory screen (0.25 mm slot width).

Recycled pulp characterization

The requested properties for recycled pulp are different in the two cases investigated in this study. For this reason, the two types of recycled pulps obtained by recovered paper processing were characterized as to different parameters, selected as a function of their applications in paper production:

Recycled (deinked) pulp for newsprint: pulp brightness (R_{457}) before and after flotation was measured on pulp pads, according to Ingede methods 1 and 2; visual inspection and measurement of tensile strength (ISO 1924-2) were performed on handsheets with a standard grammage of 70 g/m^2 (obtained on a Rapid Köthen sheet former from final deinked pulp after flotation), conditioned under standard conditions (24 h, 23 ºC and 50% RH).

Recycled pulp for packaging: the recycled fiber stock was characterized as to refining degree (^{0}SR), and long/short fiber fractions were evaluated by fractioning on an Ungger apparatus (screens no. 50 and no. 16), while the ash content and strength properties were measured on handsheets, after conditioning under standard conditions.

RESULTS AND DISCUSSION

Impact of packaging paper content in RP grade 1.11 on deinked pulp quality

Recycled pulp brightness

In deinking recovered paper, the packaging paper content impacts mainly the brightness and visual aspect of the deinked pulp and, consequently, the recycled paper (in this case, newsprint). Figure 2 plots the evolution of recycled pulp brightness, prior to (UP) and after flotation (DIP), as a function of brown packaging paper content (unusable p&b).

Pulp brightness decreases with the packaging paper content for both UP and DIP pulps. One can observe that the brightness increase (ΔB) by flotation (ink removal) declines with increasing the packaging paper content. This means that the packaging paper content does not only reduce brightness, due to unbleached fibres, but also impairs the separation and removal of ink particles. The graphs in Figure 2 present the dependence between DIP brightness and board content in recovered paper, for two experiments performed in two different laboratories, with different types of packaging paper: blue points – OCC brown/white faced (50/50) used in our study; violet points – kraftliner used in a study performed at PMW Darmstadt.[22] DIP brightness decreases linearly with the board content in both cases, with a high regression coefficient. Obviously, the slope is higher in the case of 100% brown kraftliner. This comparison shows that such experiments are reproducible and also that Ingede Method 11 is a valuable tool to evaluate the deinkability of printed recovered paper grades.

Visual aspect of deinked pulp (DIP)

Besides its effect on brightness, the content of packaging paper in deinking RP grades impacts the visual aspect of deinked pulp and, consequently, that of the obtained paper. The images of the paper sample (Fig. 4) evidence flakes of brown fibres in the DIP obtained by deinking RP with 15% brown paper content. This effect is induced by the difference between the pulping conditions (energy and pulping time) needed for packaging and graphic papers, respectively. Usually, the drum pulper is used in pulping RP grade 1.11 (mainly newspapers and magazines), since these equipments achieve a moderate shear force for defibering, so that the size reduction of contaminants, such as stickies or thin plastic foils, is avoided. However, the force is not sufficient to separate individual fibres from packaging and wet strength papers. The images also show a marbled aspect of the sheets, due to the mélange of the brown (unbleached) and white fibres.

Impact of graphic paper content in RP grade 1.04 on recycled pulp quality

Refining degree and short fibre fraction

The refining degree of recycled pulp increases almost linearly with the content of graphic paper in the model mixture (Fig. 5). The increase of the refining degree with the graphic RP content is not the effect of a refining process, but the result of the fine material content increase (short fibres, fines and filler of graphic paper). The fractionation of recycled pulp has shown that the short fibre content increases linearly with the graphic paper content in RP grade 1.04 (Fig. 6). Consequently, an increase of the graphic paper content will negatively impact

drainage (an increase in the refining degree means a decrease in stock freeness) and first-pass retention on the forming wire, as well the paper strength properties.

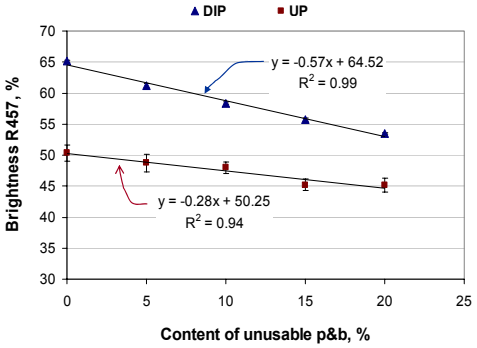

Figure 2: Effect of packaging paper content on recycled pulp brightness, before (UP) and after flotation (DIP)

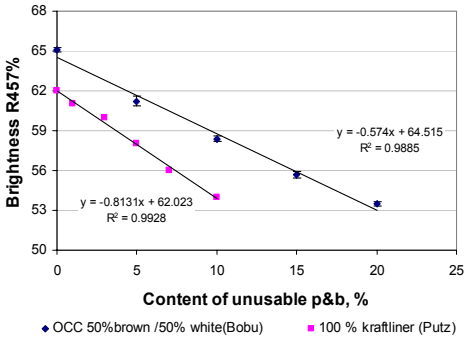

Figure 3: Comparative effect of packaging paper content on DIP brightness for two types of unusable p&b

(a)

(b)

Figure 4: Images of paper samples from DIP without (a) and with 15% packaging paper – brown/white lined corrugated board (b)

Ash content and tensile strength

The contamination of packaging with graphic paper results in an increased ash content in the recycled paper (Fig. 7), and in a corresponding decrease in paper tensile strength (Fig. 8). The ash content increases with about 1%, and breaking length decreases with about 100 m for each 5% graphic paper content in the packaging RP mixture. This allows the conclusion that the paper strength decrease is mainly due to ash increase, 100 m breaking length per 1% ash content representing a common relationship between strength and ash content.

CONCLUSIONS

Impact of packaging p&b content in deinking recovered paper grade 1.11

The content of packaging paper and board in deinking recovered paper affects strongly the optical properties of deinked pulp, by decreasing brightness and by increasing the number and size of specks due to brown fibre flakes.

To obtain a product of constant brightness from RP containing packaging p&b, paper-makers are constrained to increase the dosage of bleaching agents or to use a second bleaching stage for deinked pulp. However, none of these solutions could achieve the requested DIP brightness, if the content is too high and thus, the produced paper could be downgraded.

Impact of graphic paper content in packaging recovered paper grade 1.04

Increasing the content of graphic paper in packaging RP grades produces recycled pulp with low freeness caused by an increased fine material content – short fibres and filler, originated in graphic paper – rather than by fibre refining. A low freeness of recycled pulp means low drainage rate and low first-pass retention on the forming wire.

Increasing ash content and the short fibre fraction and decreasing the long fibre fraction result in a strong reduction of the mechanical strength of recycled pulp, which will lead to a higher consumption of strength additives for attaining the mechanical strength requested by paper product specifications.

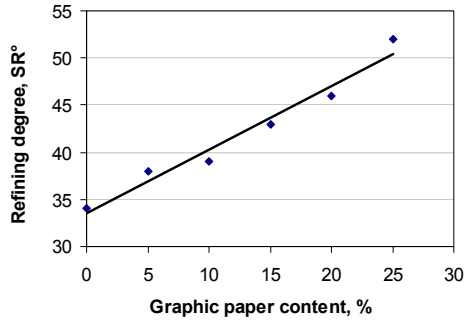

Figure 5: Refining degree of recycled pulp as a function of graphic paper content

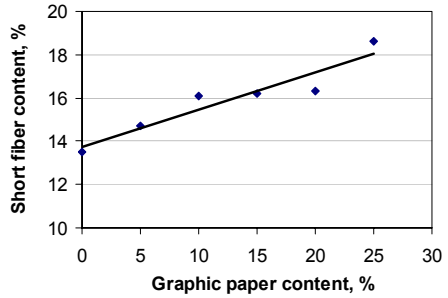

Figure 6: Short fibre fraction of recycled pulp as a function of graphic paper content

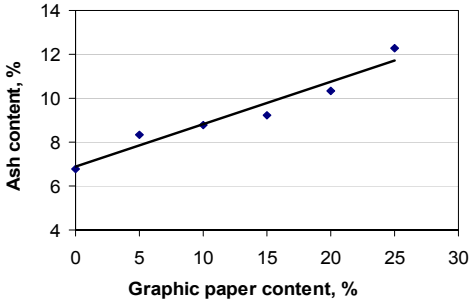

Figure 7: Ash content of recycled paper as a function of graphic paper content in packaging RP

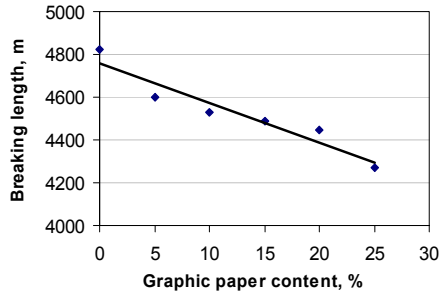

Figure 8: Breaking length of recycled paper as a function of graphic paper content in packaging RP

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