Efficient paper recycling

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Abstract: *Used paper and paper products are important raw material for paper and board industry. Paper recycling increases the material lifespan and is a key strategy that contributes to savings of primary raw material, reduction of energy and chemicals consumption, reduction of the impact on fresh water and improvement of waste management strategies. The paper recycling rate is still highly inhomogeneous among the countries of Central Europe. Since recovered paper is not only recycled in the country where it has been produced and consumed, some essential features such as eco-design and eco-collection concepts must be developed at transnational level to increase the sustainability of the paper loop. The project EcoPaperLoop addresses these needs of the regions related to paper recycling by creating a clear picture on participating region's status, by enhancing the awareness about recyclability issues as well as by improving and sharing the collective knowledge base on available technologies and practices. To put paper recycling, in terms of yield and quality, into optimum practice all across Europe, however, appropriate paper recycling strategies are of utmost importance. In present paper some findings about paper recyclability, paper recycling strategies and legislation issues will be presented.*

Keywords: *paper, paper packaging, recyclability evaluation, EcoPaperLoop project*

Introduction

Recycling creates a closed-loop system where discarded products are returned and used as raw material to manufacture a new product. In 2011, 40% of treated municipal waste was recycled or composted. Recycling is most common in Germany (45% of waste treated), followed by Ireland (37%), Belgium (36%) and Slovenia (34%) [1]. In Europe, paper is the most recycled product.

Used paper and paper products are important raw material for paper and board industry. Today 54% of the paper industry's raw material comes from recovered paper and board [2]. 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 [3]. The European paper recycling rate reached an impressive 70.4% in 2011 [4].

Paper recycling increases the material lifespan and is a key strategy that contributes to savings of primary raw material, reduction of energy and chemicals consumption, reduction of the impact on fresh water and improvement of waste management strategies. Main target of EcoPaperLoop, a Central Europe Project is to raise awareness and provide tools to enhance the recyclability of paper products as well as the collection of paper for recycling in the Central Europe region in order to encure good quality raw material for the paper industry and reduce environmental impact [5]. Background of the projects is amongst others a report on how EU members manage their municipal waste. The Environment Commissioner Janez Potočnik is alarmed: "Many Member States are still landfilling huge amounts of municipal waste – the worst waste management option – despite better alternatives, and despite structural funds being available to finance better options. Valuable resources are being buried, potential economic benefits are being lost, jobs in the waste management sector are not being created, and human health and the environment suffer. This is hard to defend in our present economic circumstances" [6].

Recyclability of paper products

The use of paper for recycling as a raw material involves a multi-stage treatment of paper for recycling including, separation and elimination of contaminants in order to obtain recycled pulp. For good recyclability, paper products have to be repulpable and adhesives have to be removable. That is important for all types of paper products. For all white grades paper must be also deinkable. The term deinkability, expressing the ability of a printed product to be deinked, is defined as removal of ink and/or toner from a printed product to a high extent by means of a deinking process. This shall restore, as well as possible the optical properties of unprinted product [7].

Recyclability Evaluation for Graphic Papers

For printed papers deinkability test is mostly performed according to INGEDE Method 11, which simulates at a laboratory scale pulping and flotation, and serves as a basis for comparing the deinkability of prints. Prior to pulping, the samples undergo a 3 day artificial ageing, which is equivalent to an about 3 month natural ageing. Pulping, storage and flotation are exactly defined by equipment and operating parameters [7]. According to INGEDE Method 11 five parameters are evaluated: luminosity, dirt area and a* value of deinked pulp, ink elimination and filtrate darkening. The first three are quality parameters characterizing the deinked pulp as to brightness and cleanliness (luminosity Y, dirt particle area A). The dirt particle area is subdivided into two results – the area of particles larger than 50 μm in diameter, which represents all particles visible to the naked eye, and the area of particles above 250 μm in diameter. Additionally, the colour shade on the red-green axis of the deinked pulp is determined by the a* value. The last two are process parameters (ink elimination, IE; discoloration of filtrate, ΔY), offering information on the possible effects of ink carry-over on deinking [7].

Results of deinkability tests achieved by means of INGEDE Method 11 are converted into Deinkability Scores. For each of the five parameters – luminosity, colour, cleanliness, ink elimination and filtrate darkening – threshold and target values are defined. The target values depend on the category of the printed product; whereas thresholds are the same for all categories [8]. For a given print product, the threshold values listed in Table 1 have to be fulfilled for all parameters. If one or more threshold levels are not reached, a print product is judged as "not suitable for deinking". According to Table 2, target values are set for each group of print products and for each parameter. If the target value of a parameter is met, the full score is given for this parameter. The maximum scores of the individual parameters have different values, which reflect their importance. The parameter luminosity of the deinked pulp has, with a ratio of 35%, the most significant effect on the total deinkability score, followed by dirt particle areas (25% as total of A50 (15%) and A250 (10%)), colour (20%) of the deinked pulp and the two process parameters: ink elimination and filtrate darkening (10% each). For each individual parameter, the ratio of units better than the threshold value, divided by the range between threshold and target values, multiplied by the maximum score for this parameter, gives the Deinkability Score for this parameter.

Table 1: Threshold values of deinkability scores

	Y [Points]	**a* [-]**	**A50 [mm²/m²]**	**A250 [mm²/m²]**	**IE [%]**	**ΔY [Points]**
Lower threshold	47	-3	/	/	40	/
Upper threshold	/	2	2000	600	/	18

Table 2: Target values of deinkability scores

Print product categories	Y [Points]	a* [-]	A50 [mm²/m²]	A250 [mm²/m²]	IE [%]	ΔY [Points]
Newspapers	≥ 60	≥ -2 to ≤ 1	≤ 600	≤ 180	≥ 70	≤ 6
Magazines, uncoated	≥ 65	≥ -2 to ≤ 1	≤ 600	≤ 180	≥ 70	≤ 6
Magazines, coated	≥ 75	≥ -2 to ≤ 1	≤ 600	≤ 180	≥ 75	≤ 6
Stationery (Y of base paper ≤ 75)	≥ 70	≥ -2 to ≤ 1	≤ 600	≤ 180	≥ 70	≤ 6
Stationery (Y of base paper ≥ 75)	≥ 90	≥ -2 to ≤ 1	≤ 600	≤ 180	≥ 80	≤ 6

Finally, the score of all five parameters is added up to provide a single number between 0 and 100 points, corresponding to the total score for a particular print. If one or more threshold values fail, the print product is considered unsuitable for deinking, though it can be well recyclable. If all thresholds are reached, the product is judged as deinkable with three various gradations: poor, fair or good (Table 3).

Table 3: Rating of the deinkability scores

Score	Evaluation of deinkability
71 to 100 points	Good
51 to 70 points	Fair
0 to 50 points	Poor
Negative (failed to meet at least one threshold)	Not suitable for deinking

Another product-related quality aspect is the ability to remove adhesive applications, which form tacky particles in the paper recycling process. Stickies is a broad term for all tacky components in the recovered paper pulp and are classified according to their sources as primary, resulting from recovered paper and secondary, originating from recycling process [7]. Depending on their size and their behaviour they are called macrostickies, microstickies or potential secondary stickies. Macro- and microstickies are distinguished by their separation behaviour under a standard screening process at a laboratory scale. The recommended criterion is a plate with a slot width of 100 μm, also 150 μm for pulps from paper for recycling or for packaging papers. For an assessment method under laboratory conditions, not only the screening, but also the pulping process has to be defined. By INGEDE Method 12, adhesive applications are pulped together with deinking chemicals and woodfree copy paper, which is free of stickies. After screening the reject is prepared and measurement of stickies (number and size) are done by image analysis. Results of macrosticky measurements achieved by means of INGEDE Method12 are converted into Removal Scores. There is a threshold defined for the share of the macrostickies below 2000 μm. A share above this threshold results in a negative score and is assessed as "insufficiently removable". The area below 2000 μm particle size has a scoring limit [9].

One of the factors, which defines the efficiency of industrial screening processes, is the particle size distribution of macrostickies. The larger the macrostickies are, the better is their removal efficiency by screening. The screening efficiency can be determined as presented in Table 4. The assessment of removability consists of two parameters. It is beneficial that the total amount of macrostickies is low, and therefore the amount receives higher score than the share. This area therefore can achieve up to 80 points. The higher the share of macrostickies below 2000 μm, the higher the danger is of having many stickies below the detection limit of the method. Therefore

the share of macrostickies below 2000 μm has a threshold at 50%. Lower shares obtain up to 20 points. For scoring the theoretical macrosticky area in the pulp after industrial screening is 5000 mm^2/kg product and the target value for the theoretical macrosticky area is < 500 mm^2/kg product, whereas the target value for the share of macrosticky area is < 10% [9].

Table 4: Removal efficiency as function of the macrosticky particle size

Size class of macrostickies	**Removal efficiency**
< 600 μm	0 %
600 μm to 1.000 μm	20 %
1000 μm to 2.000 μm	80 %

Results of the individual parameters, which meet or exceed the target values, receive the maximum scores for these parameters. "Exceeding the target values" means that the result has to be lower than the target value. If this is not the case, the score has to be calculated by linear interpolation.

Table 5: Rating of the Removal scores

Score	**Evaluation of removability**
71 to 100 points	Good
51 to 70 points	Fair
0 to 50 points	Tolerable
Negative (failed to meet the threshold)	Insufficient

Recyclability Evaluation for Packaging Products

Packaging products have to fulfil recyclability requirements; i.e. repulpability and removability of adhesives, to ensure improved recycling cycles. The potential problems when recycling a specific piece of packaging: it can be difficult to disintegrate, it can contain non-paper components such as plastic films and it can include adhesives that are difficult to remove during the recycling process. Recyclability evaluation for packaging products is necessary, but there is a lack of common laboratory method for testing the recyclability in different countries [10].

At Darmstadt Technical University, Chair for paper technology and mechanical process engineering (PMV) a new assessment tool to evaluate the recycling performance of paper packaging products has been developed. Goal of the procedure is the simulation of the behaviour of packaging material during the stock preparation of a paper mill. During the investigation the packaging material is probed considering the content of non-paper components, content of difficult to disintegrate material, the flake content and the macrosticky potential. Packaging is disintegrated in a low consistency pulper. The suspension with the whole volume is then filled into the screening device and agitated, then drained through a screen with 10 millimetre holes. The reject is washed, dried and weighed. Assessment includes evaluation of non-fibre components, flake content and sticky content e. g. share of stickies < 3.000 μm. The macrosticky content is determined according to INGEDE Method 4: The reject is transferred to a paper filter, stained with black ink, then the sticky rejects visualised with white, special fused alumina powder. The sticky area is evaluated by image analysis and counted as area per kilograms of product. The Scoring System is analogue to Deinkability and Removability Scores of graphic papers [11].

(a) (b)

Figure 1: Determination of flake content (a) and macrosticky content (b) [12]

Collection strategies

Out of the total volume of paper for recycling collected, the outputs of paper mills are: 63% packaging applications, 27% information applications (19% newspapers, 8% other graphic papers), 7% hygienic-household uses and 3% other uses. In summary, most of the paper for recycling is used in packaging, followed (by a significant difference) by information applications, mostly newspapers [13]. Improper collection systems can drastically reduce the amount of paper being recovered for recycling; and improper design of a graphic or packaging product can make it useless or even harmful for the recycling process [14].

The theoretical limit of paper and board recycling rate is around 81%, since 19% of paper products are not collectable or recyclable for technical reasons [15]. In addition to non-collectable and non-recyclable paper, it may not be economically or environmentally friendly to collect and recycle everything that, in theory, would be technically feasible because this could require extra costs such as increased transportation. Generally, there is a lack of data on collection, collection rates and recycling rates by specific grades of paper (for example, for office printings, or for newspapers, etc.), partly due to the fact that many of the waste paper streams consist of mixtures of different types of papers.

Used paper and cardboard are collected for recycling by municipal or private organizations, and delivered to reprocessing plants. Paper can either be sorted at source, or disposed of mixed with other household, office or commerce waste, whereas paper from industry is in most cases homogeneous and sorted. Paper mixed with household, office or commerce waste can be sorted mechanically, but in general the quality of the paper sorted this way is not as high as from separate collection systems.

The applied systems for collecting paper are different in different countries or regions: a) bundle, sack or otherwise loosely provided collected under municipal service, b) bins or containers, c) bring banks, d) reception points, informal collectors or private vendors, service firms or vendors, reverse collection from logistic firms, firms specialized on data destruction, e) single stream commingled collection.

The bulk of paper for recycling in Europe originates from separate collection at source, including industrial sources (e.g. printing industry), offices (private and public), large commercial businesses (e.g. supermarkets, furniture) and households (bring or door-to-door collection). In some countries graphic paper is collected separately from packaging paper and board [14].

An analysis of the paper and board collection rates within Europe clearly suggests that there is still a considerable potential of used paper and board suitable for recycling which is not being tapped yet. The efficiency of a collection system for used products is in general assessed with regard to quantity and quality of the collected material and the specific collection costs (€/t). All corresponding studies gave clear evidence that the success of such strategies is

moreover a function of the local/regional society's environmental awareness, the local/regional infrastructure, the structure of the local/regional recycling industry and the way the collection strategy addresses the needs of this local/regional recycling industry [16].

At a European level, a rough estimation indicates that 50% of the paper for recycling is collected from industry and trade, 40% from households and 10% from offices, although these percentages differ greatly among countries and collection systems employed. As high quality and easily collectable sources are well-exploited, the potential for a collection increase lies in small sources, with high spreading and contamination, mainly from household collection, which could result in decrease in recovered paper quality [15].

Legislation

In the EU the management and trade of used paper are currently under waste regulation, the Waste Framework Directive and the EU Waste Shipment regulation. The production of paper and the associated treatment of waste paper on site are subjected to the IPPC Directive. Packaging paper is also regulated under the Packaging Directive.

The legal framework covering paper recycling has some discrepancies and contradictions. For example, in some standards (EN 643) used paper is recognized as a valuable input or raw material, though it is not recognised as such by law; recyclability is a part of waste problematic, whereas for industry it is a part of its raw material procurement. Another example is connected to Directive 2001/77/EC, which promotes the electricity from RES (biomass, including materials from forestry and related industries). The RES identifies pulp and paper residues as renewable energy sources. A clear emphasis should be put on promotion of paper for recycling and recognition of material recycling priority towards energy recovery. Only, once recycled 5 or 6 times, paper should be transformed into energy [17].

The Waste Framework directive (2008/98/EC) introduces the possibility that certain waste streams having undergone a recovery operation and fulfilling certain criteria – so-called End-of-waste criteria – can cease to be waste. The criteria have to ensure that the waste streams fulfil a number of conditions, including the existence of a commonly used specific applications, existence of a market or a demand, fulfilment of technical requirements for the specific applications, meeting existing legislation and standards applicable to the products the waste streams substitute; and the absence of any overall adverse environmental or human health impacts [13].

Waste paper shall cease to be waste where, upon transfer from the producer to another holder, or prior to its use at a paper mill, it complies with all the following criteria and conditions [13]:

- The waste paper shall be graded according to the European specification 69 „EN-643- Paper and board - European list of standard grades of recovered paper and board".
- The non-paper component content shall be ≤ 1.5% of air dried weight.
- The waste paper, including its constituents and in particular ink and dyes, shall not display any of the hazardous properties listed in Annex III of Directive 2008/98/EC. The waste paper shall comply with the concentration limits laid down in Commission Decision 2000/532/EC72, and not exceed the concentration limits laid down in Annex IV 850/2004/EC73 of Regulation
- Waste paper must not contain absorbed oil, solvents, paint, aqueous and/or fatty foodstuffs, that can be detected by visual inspection.
- Waste paper streams used, as input shall, once received by the producer or importer, be kept permanently separate from the contact with any other waste, including other waste paper grades.
- All treatments needed to prepare the waste paper for direct input to pulping in the manufacture of paper products, such as sorting, separating, cleaning, or grading, and except de-baling, shall have been completed.

In the field of collection, sorting, recycling, use and trade of paper and board for recycling there are regulations, laws, decrees and other legal documents that differ from country to country. It is important that policies applied don't distort the market of separately collected paper and board. Supply side collection programs, mandatory and voluntary, have probably exerted the most significant and lasting influence on paper recovery and recycled fibre supply.

Conclusions

Since paper for recycling is not only recycled in the country where it is produced, some essential features such as eco-design and eco-collection concepts must be developed at transnational level to increase the sustainability of the paper loop.

The goal of EcoPaperLoop project is to expand the database on recyclability and deinkability of graphic papers that already exist in some countries (Germany, Italy) to other central European countries (Poland, Hungary, Slovenia). On the basis of extensive assessment campaign a wide database on packaging recyclability in Germany, Italy, Poland, Slovenia and Hungary will be created. A scorecard proposal based on project results will constitute the main output of this activity.

By comparing quality of paper for recycling versus different collection systems in the CE region, recommendation guidelines on sustainable paper collection strategies in the region will be delivered.

Based on analysis of present body of rules another planed output of the project will be stimulating new policies to enhance quality of paper for recycling in Central European region.

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