ANALYSIS OF THE QUALITY OF THE RECOVERED PAPER FROM COMMINGLED COLLECTION SYSTEMS

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ABSTRACT

The need to increase the recovery rates of recyclables from households, reducing at the same time the collection costs, has favored the spreading of commingled collection systems. This study presents a thorough analysis of the quality of a secondary source of recovered paper of a Spanish newsprint mill, imported from the United Kingdom, where these systems are widely practiced. The results show that the quality of recovered paper from commingled systems is very far from the quality obtained with selective systems: the unusable material content vary from 1% to 29% (11.9% on average) compared to less than 1%. Larger materials recovery facilities (MRF), less oversaturated and with advanced sorting techniques, have demonstrated to be able to render better qualities, the unusable material content varying from 0.3% to 16.6% (8.1% on average). However, the quality is still far from contamination levels typically found with selective systems, especially in terms of non-paper components. This fact limits significantly the use of this recovered paper for graphic paper production where the major potential for an extended use of recovered paper in papermaking lies. Furthermore, there is a discussion on the cost efficiency of these systems and how the legislation and private or public initiatives are affecting the spreading of these systems, especially in the United States and the United Kingdom.

Keywords: recovered paper; quality; unusable materials; commingled collection; sorting; materials recovery facility (MRF)

1. INTRODUCTION

The recovery and utilization of recovered paper has increased over the last decades all over the world, and this trend will continue due to economic, environmental and social reasons. Paper recycling is already at very high levels in some regions, e.g. a recycling rate of 70.4% was achieved in 2011 in Europe despite the world economic crisis (CEPI, 2012). However, there is still room to further extend the limits of paper recycling. In this scenario, quality of the recovered paper is a crucial issue for achieving higher recycling rates while maintaining the sustainability of the whole process (Miranda et al., 2010).

Quality of recovered paper is affected by different issues. One important issue is the continuous need to increase its availability. It is well known that higher recoveries are always detrimental to the quality of paper collected, especially when the collection rates are already high (Miranda et al., 2011). The reason is that, firstly, the easy-to-collect and the highest quality sources of used paper are exploited while, by an increased demand, the recoveries increase by exploiting other lower quality and more disperse sources such as the recovered paper from households. When the collection rates are already high, industrial and trade sources are tapped and possible increase of recovery is almost only based on households (Faul, 2005; Levlin et al., 2010; Miranda et al., 2011).

The method of collection is another factor which has a direct impact on recovered paper quality (Faul, 2010). Separate collection systems can render slightly different qualities of recovered paper but the most important differences on quality are observed when separate and commingled collection systems are compared. In fact, the shift from source-separated collection systems to commingled systems has been considered as one of the most significant changes in the recycling industry in the last years and one of the major threats to the recovered paper quality (Miranda et al., 2010; Sacia and Simmons, 2006).

In commingled collection systems, all recyclable materials are collected together in a single container, and include a mix of paper, board, glass bottles, cans, plastics, etc. Although the materials are next sorted in a materials recovery facility (MRF), cross contamination is more likely. Thus, total unusable materials present in recovered paper vary between 5 and 20%, depending on the cases, compared to less than 1% for source-separated collections (Kinsella, 2006; Kinsella and Gleason, 2003; Read, 2009; WRAP, 2006).

Unusable materials content is one of the most determining factors on the quality of recovered paper. According to the European List of Standard Grades of Recovered Paper and Board (EN 643), unusable materials consist of non-paper components and paper and board detrimental to production of he finished product (Table 1). Non-paper components consist of any foreign matter which during processing, may cause damage to machines or interruptions to production or may reduce the value of the finished product. Paper and board detrimental to production are grades of paper and board which have been recovered or treated in such a way that they are, for a basic standard level of equipment, unsuitable as raw material for the manufacture, or are actually damaging, or whose presence makes the whole consignment of paper unusable. In the case of graphic papers such as newsprint, light weight coated or supercalendered papers, all old newspapers (ONP) and old magazines (OMG) belong to the desired papers and all brown and gray packaging is classified as unsuited. However there are also household waste papers for which the rating is not as clear and every paper mill set its own specifications depending on the recovered paper grades purchased and the type of recycled paper grade which is produced (Faul, 2005).

Table 1.- Definition of unusable materials in recovered paper for graphic paper production.

<table>
<tr><td rowspan="2">Total unusable materials (or total unwanted materials)</td><td>Non-paper components (or prohibitives)</td><td>Metal, plastic, glass, textiles, wood, sand and building materials, synthetic materials, synthetic papers, dirt, cloth, rope, string, garbage, rubber bands, personal absorbents (diapers, pads, etc.).</td></tr>
<tr><td>Paper and board detrimental to production (outthrows or unwanted materials)</td><td>Old corrugated containers (OCC), Kraft bags, folding carton, telephone books, carbonless paper, colored paper, envelopes, catalogs, stickies, carbon paper, junk mail, wax paper.</td></tr>
</table>

Most of the collection companies and local governments operating commingled collection systems are pleased with the results as they increase recovery rates and reduce collection costs (Emerson, 2004; Faul, 2005; Kinsella and Gertman, 2008; WRAP, 2004; WYG Environment, 2012). In addition, they appreciate these systems because they reduce worker compensation costs, the number of trucks on the road and often allow additional materials to be added to the collection system. However, for many recycled-product manufacturers, these systems are problematic due to higher processing costs, and ultimately, the losses associated with higher levels of contamination of the products.

Since around 75% of curbside collection is paper fiber (Kinsella, 2006; McClelland, 2010), paper mills are hardest-hit, with plastics, glass and metals all ending up in their recovered fiber. Higher contamination levels result in lower process yield, higher maintenance cost, handling greater amounts of trash, lower quality products, etc. (Contamination in Commingled Recycling Systems Standards & Guidelines Initiative, 2009; Haynes et al., 2009; Kinsella, 2006; Sacia and Simmons, 2006). From a purely paper reprocessing point of view, it is doubtful whether the benefits of cheaper collection of commingled recyclables outweighs the extra costs of higher processing costs (sorting) and the removal of more contaminants during the papermaking process.
Commingled collection systems are widely spread in some countries, like the United States and the United Kingdom, and they are been spreading to other European countries such as France (Faul, 2005). In the United States, single-stream recycling has been an emerging trend for several years: in 2000, around 11% of the population with recycling programs had access to a single-stream programs, while this number increased to 29% in 2005, 50% in 2007 and 65% in 2010 (AF&PA, 2011). In the United Kingdom, the number of municipalities using commingled systems had also increased sharply in the last few years. The proportion of recovered paper from households commingled collection rose from 19% in 2003/04 to 30% in 2005/06 and to over 40% in 2007/08, and without any doubt, will be higher than 50% at present (WRAP, 2008; WRAP, 2010).

The objective of this study is to analyze the impact of the use of commingled collection systems on the quality of recovered paper collected from households and how modern MRFs, with larger capacitites and modern sorting technologies, can help to reduce the level of contamination. Furthermore, the use of commingled systems will be analysed reviewing its effect in paper manufacturing and its cost efficiency (still under debate), and how is affected by new regulations and initiatives.

2. METHODOLOGY

The quality of the recovered paper from commingled collection systems has been approached analysing a secondary source of recovered paper used by the largest Spanish newsprint mill (300,000 tons/year), based on 100% recovered paper. This mill uses different recovered paper grades as raw materials, with shares of each grade varying with time, the availability of the raw materials, and the final product requirements. In general, it can be said that around 50-60% of the recovered paper used as raw material at this mill is a sorted mixture of old newspapers (ONP) and old magazines (OMG) from households. In addition, the mill uses unsold newspapers and magazines, both used at approximately the same proportion, together representing 30-35% of the raw material. The remaining 5-20% are different grades from other sources, including some high quality grades such as white shavings from printing and converting operations and low quality grades such as recovered paper from households collected by commingled collection systems (imported from the United Kingdom).

This source is mainly used during summer due to the important scarcity of recovered paper in the centre of Spain, where the paper mill is located, due to population movements on holidays. Great efforts have been made during recent years in Spain to substantially increase the volume of recovered paper and the collection rates, however, there is still some shortfall which needs to be balanced by imports from neighbouring countries (Miranda et al., 2011).

Two comprehensive studies have been carried to monitor the quality of this source. The first study covers the period June-September 2007, where 191 samples were analyzed. The second study covers a longer period, from May 2008 to June 2009, with 327 samples analyzed (50 samples during 2008 and 277 samples during 2009). Table 2 shows the number of samples analysed per month for both studies. The main difference between these surveys is that between the two periods, the supplier built its own MRF with modern sorting technologies to improve the quality of the outcoming paper. This supplier is owned by a paper company with paper mills in different locations producing graphic paper, as the paper mill in Madrid used as a basis for this study. Previously, the supplier buys the recovered paper from a number of different MRFs stations in the United Kingdom, which were giving not acceptable qualities of recovered paper as those demanded by their paper mills. Therefore, data from Study 1 reflect the average quality of the recovered paper from MRFs of the United Kingdom, while data from Study 2 reflect the quality of the recovered paper from this new MRF.

Table 2.- Monthly average unusable material content from Study 1 and Study 2.

Study 1 (N=191 samples)		
Month	**No. samples**	**Average unusable material content (%)**
June 2007	56	11.47
July 2007	44	8.68
Aug. 2007	52	8.58
Sept. 2007	39	11.05
Study 2 (N=327 samples)		
Month	**No. samples**	**Average unusable material content (%)**
May 2008	8	10.60
June 2008	5	13.56
July 2008	13	8.31
Aug. 2008	10	6.96
Sept. 2008	7	8.07
Oct. 2008	3	4.99
Nov. 2008	3	8.49

Dec. 2008	1	7.16
Jan. 2009	68	7.41
Feb. 2009	64	8.23
Mar. 2009	65	7.69
Apr. 2009	51	8.15
May 2009	17	9.11
June 2009	12	9.34

Unusable material content was used to assess the quality of the recovered paper. It was determined by gravimetric analysis from selected samples of recovered paper of approximately 40 kg, before and after the isolation of all the unusable material present, according to the general definitions of the European List of Standard Grades of Recovered Paper and Board (EN 643). As it has commented previously, unusable materials content is the sum of non-paper components and paper and board detrimental to production. In this study, focused on graphic paper production, all the brown and grey board were considered to be detrimental to production as well as carbon paper, wet-strength papers, colored papers, paper with glue or polycoated or with waxes and paper treated with non-water soluble adhesives.

Statistical analysis of the samples has been carried out using Statgraphics® software, version Centurion XV. To determine if the samples comes from a population with a specific distribution, chi-square and Kolmogorov-Smirnov tests were carried out. The chi-square and Kolmogorov-Smirnov are alternative goodness-of-fit tests, with the following main differences: chi-square test can be applied to discrete distributions and is generally used for small samples while the Kolmogorov-Smirnov test is restricted to continuous distributions but used for large samples. This issue is of importance as many statistical tests and procedures are based on specific distributional assumptions and the assumption of normality is particularly common in classical statistical tests.

3. RESULTS

Study 1 (June-September 2007). A summary of the statistical analysis of the results is presented in Table 3. Unusable material content varied in a wide range, from 1.1% to 29.0%. The average value was 11.9%, with a standard deviation of 6.48%, and the median value was 11.7%.

Table 3.- Statistically analysis of unusable materials content from Study 1 and Study 2.

	Study 1	**Study 2**
Number of samples	191	337
Average	11.94	8.11
Confidence interval (95%)	±0.77	±0.23
Std. deviation	6.48	2.53
Variance	41.98	6.42
Minimum	1.06	0.35
Maximum	29.05	16.61
25th percentile	8.40	6.41
50th percentile	11.66	7.91
75th percentile	15.14	9.60
90th percentile	18.56	11.32
95th percentile	20.81	12.60
99th percentile	25.91	14.99

Figure 1 show the relative and cumulative frequency distribution curves of the analyzed samples. Most samples (88%) are in the central intervals, from 5 to 20%, while the number of samples with unusable material contents lower than 5% or higher than 20% are similar and represent each around 6% of the samples. Chi-square and Kolmogorov-Smirnov tests demonstrated these data comes from a normal distribution with 90% confidence.

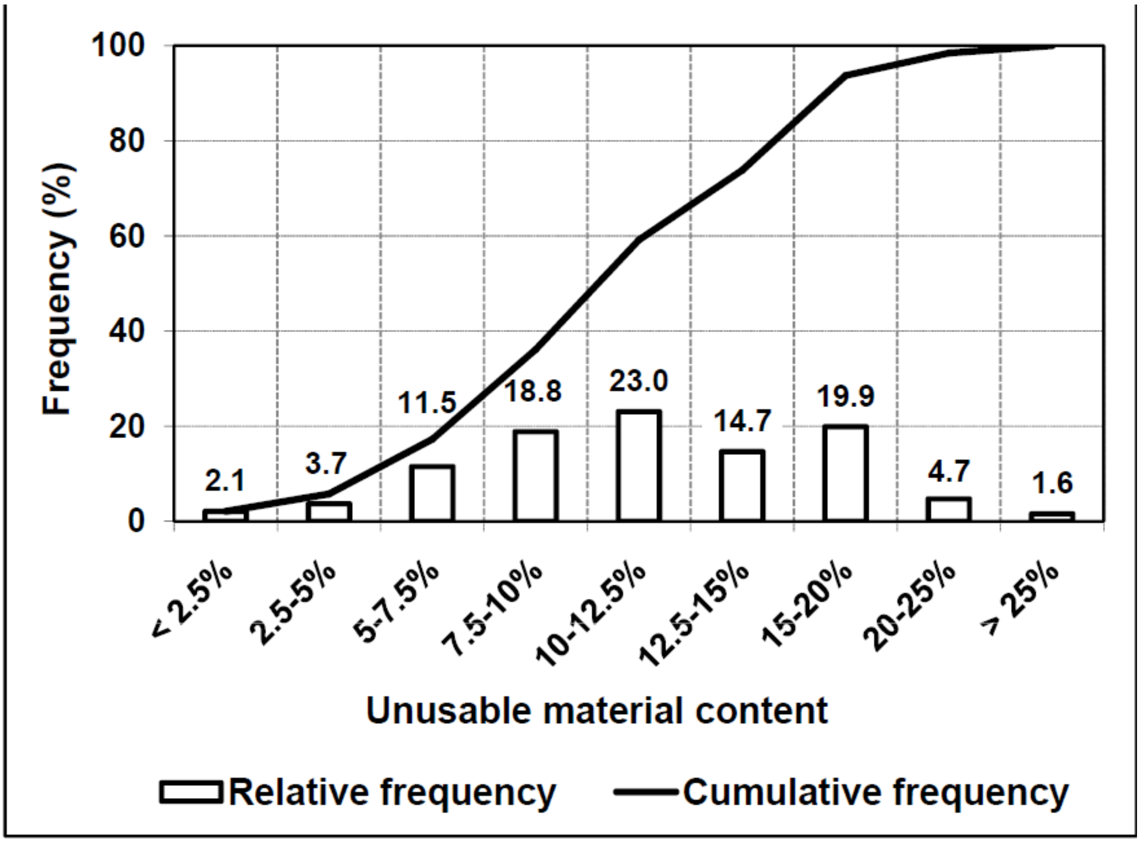

Figure 1.- Relative and cumulative frequencies by intervals of unusable material content during Study 1 (June-September 2007).

The monthly averages of the four analysed months are very similar: 13.1% in June 2007, 11.4% in July 2007, 10.5% in August 2007 and 12.5% in September 2007 (Table 2). However, more data from the same month and different years would be necessary to determine if there are any monthly or seasonal trends as, for example, has been demonstrated from paper collected from households by selective collection (Miranda et al., 2011).

Study 2 (May 2008-June 2009). A long-term study with higher sampling frequency was carried out to determine the effect of the installation of a new MRF. This MRF was equipped with the most modern sorting technologies, with a high degree of automation, which represented the state-of-the-art technology when installed. The study analysed the total unusable material content of 327 samples: 50 samples in 2008 (6 samples per month on average) and 277 samples in 2009 (46 samples per month on average) (Table 2).

In this period, unusable material content ranged from 0.35% to 16.6%. The average unusable material content was 8.11% and the median was 7.91%. Figure 2 shows the relative and cumulative frequency distribution curves of the samples. In this case, the relative frequency distribution curve is sharper than in the study 1, with most of the samples (75% of samples) between 5% and 10%. Furthermore, around a 95% of the samples were in the 5-15% range. It is remarkable that only 0.9% of the samples had an unusable material content higher than 15% and there are no samples with higher contents than 20%, which is very significant when compared to the results before the installation of the new MRF (Study 1). On the other hand, the share of samples with lower unusable material content than 5% is almost the same in both studies: 5.8% in Study 1 and 5.7% in Study 2. Chi-square and Kolmogorov-Smirnov tests have demonstrated that data from Study 2 do not come from a normal distribution, with 99% confidence, however, data from Study 1 can be considered as coming from a normal distribution, although with a less confidence level (90%).

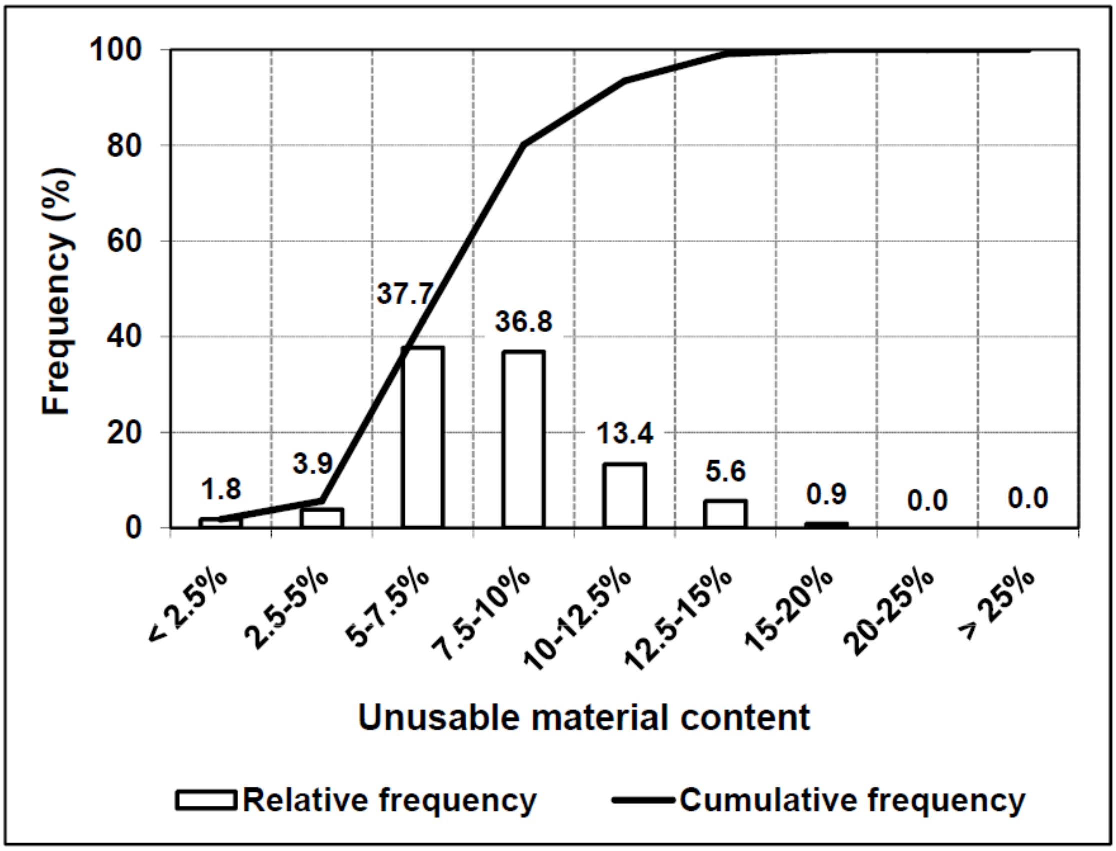

Figure 2.- Relative and cumulative frequencies by intervals of unusable material content during Study 2 (May 2008-June 2009).

When monthly averages are considered, again no significant trends were observed (Table 2). Only significant variations occurred in some months of 2008 but these variations occurred in the months with lower number of analysed samples, i.e. 5.0% in October 2008 (3 samples) and 13.6% in June 2008 (5 samples,) indicating these variations are not statistically relevant. During 2009, when the sampling frequency was higher, only minor monthly variations were observed.

4. DISCUSSION

4.1. Impact of the sorting technology and production capacity of MRF on recovered paper quality

The average values for total unusable materials are in agreement with published data from commingled collection systems, especially from English MRFs, which vary from 5% in the best cases up to 20% (Kinsella, 2006; Kinsella and Gleason, 2003; Read, 2009; WRAP, 2006). In both Study 1 and 2, 88% of the samples were within this range. In addition, the samples with unusable material contents lower than 5% are very similar in both studies (around 6%). However, as it was commented before, there are very important differences regarding the number of samples with the highest unusable material contents. Furthermore, the relative frequency distribution is narrower in Study 2 than in Study 1. In Study 2, an 88% of the samples were between 5-12.5% and still a 74.5% between 5-10%, while for Study 1 these values are 53.3% and 29.8%, respectively.

Comprehensive studies on the quality of recovered paper have been carried out within the members of the International Association of the Deinking Industry (INGEDE). This Association is formed by 34 paper mills, mostly European, utilising more than 10 million tons of recovered paper per year. According to Faul (2005) the limits for total unusable material content varies from 1% to 6% in most of these mills. Therefore, contents higher than 7.5% would be very difficult to be accepted by these mills unless there is an important scarcity of raw material. This means that more than 80% of the samples in Study 1 and 57% in Study 2 could not be fully utilisied for graphic paper production (unusable material content > 7.5%). In addition, there is still a 56.5% of the samples with unusable material content between 7.5% and 15% in Study 1 (55.8% in Study 2), and 26.2% higher than 15% in Study 1 (only 0.9% in Study 2).

After the installation of the new MRF, the situation clearly improved. Average unusable material content decreased from 11.9% (Study 1) to 8.11% (Study 2), and the median unusable material content decreased from 11.7% to 7.91%. Therefore, average and median unusable material contents were reduced by 32%. Even more important, the percentage of samples with unusable material contents lower than 10% increased from only 36.0% in Study 1 up to 80.2% in Study 2, which is a great achievement.

The decision to install a new MRF was taken because the majority of the existing facilities operating around the United Kingdom were producing end products that regularly fell short of the quality standards required by paper mills supplied. To maintain the quality of supply, the collection company decided to build its own MRF to control theirselves the quality of the outcoming paper to achieve the quality standards demanded by the (graphic) paper mills supplied. Table 4 summarizes the main differences between the MRFs from Study 1 and Study 2.

Table 4.- Comparison between the MRFs sorting the recovered paper from Study 1 (average behaviour of the MRFs in the United Kingdom) and Study 2 (new and automated MRF owned by the paper mill). Source: WRAP (2006, 2007); Marley (2007a).

	Study 1	**Study 2**
Capacity	81% MRFs < 50,000 tons/year 59% MRFs < 25,000 tons/year	120,000 tons/year
Economies of scale	Not possible	Applied
Sorting technology	Mainly manual	Mainly automated
Sorting cost	High	Intermediate
Running above capacity?	Common	No
Level of sorting	Regular	High
Pre-sorting	Not incorporated in all MRFs	Yes
Separation of fibre from containers	One or two screening stages, depending on MRF size (disc screens / trommels screens)	Three stages of screening (star-shaped screens)
Sorting paper into grades	Mainly manual, some automation is possible depending on MRF size	Automated with two disc screens

Residue rates	High (reprocessing of residue is usually avoided)	Intermediate (reprocessing of residue is carried out when necessary)

It is known that the quality of recovered paper from English MRFs is not as good as in other countries. English MRFs are not achieving the quality standards of 3rd or 4th generation MRFs of North America and Europe. This shortfall is largely a result of experience, MRF size and the lack of sophisticated sorting technology, the latter only affordable to MRFs with economies of scale. The United Kingdom Waste and Resources Action Programme (WRAP) studies indicate that 50,000 to 80,000 tons/year is the threshold for economies of scale, and that 81% of England's MRFs are below 50,000 tons/year (Marley, 2007a; WRAP, 2006). For this reason, the unit cost per tonne rises significantly at lower throughput tonnages, i.e. the unit cost per tonne of a 40,000 tons/year facility operating at full capacity can be estimated in £60/ton, compared to £40/ton for an 80,000 tons/year facility (WRAP 2007). In North America, for example, Waste Management has closed and merged most of its smaller MRFs (under 50,000 tons/year) and is transporting collected curbside materials over 100 miles to be sorted at larger facilities (WRAP, 2006).

In addition, some English MRFs are being run above capacity, which affects the quality of recovered paper (Anon, 2008). The costs pressure for segments of the recovered paper supply chain counteracts often against possible and necessary quality improvements of the recovered paper: there is a strong pressure to speed up the sort line and to reduce costs by minimizing sorters (Contamination in Commingled Recycling Systems Standards & Guidelines Initiative, 2009; Miranda et al., 2010; Wagner et al., 2007). Automatic sorting processes can help to reduce efficiently the costs, but they are only possible if the economy of scale is present (Marley, 2007a; Wagner et al., 2006). The larger plants with more sophisticated technologies, such as the one installed by the studied collection company, are completely necessary to produce the qualities demanded by paper mills. This is especially important for graphic paper production, where mainly lies the potential growth of the use of recovered paper for paper recycling (Faul, 2005; Miranda et al., 2010). The new MRF installed is one of the largest single-line MRFs in Europe with a capacity of 120,000 tons/year, at an investment of around $9 million. The plant is based on automatic screens (that segregate the recyclables by size, weight or density), and manual sorting. First, bags of commingled dry recyclables are put through a Matthiessen bag splitter before an initial picking line, to pick out obvious contaminants. The material is then put through a series of glass breakers, to remove glass, and American “star-shaped” screens which separate flat paper and card from round bottles and cans. At the end of the process, the material is handpicked again and run over a magnet and eddy-current separator to remove the metal. One of the most important improvements of this MRF is that uses glass breakers and screens which are believed to be more efficient than trommels.

Due to the improvements on the quality of this source and the continuous scarcity of recovered paper in Spain, the share of recovered paper from this source in the feedstock of the analyzed mill increased from around 2% in 2007 to 4% in 2008 and 2009. The mill aims to increase the use of this source of recovered paper but only if the quality is maintained within certain limits. However, this recovered paper is still of a very low quality compared to other sources, therefore, its use is limited to low shares in the feedstock to avoid the associated detrimental consequences in the process.

4.2. Limits in efficient recycling of recovered paper from commingled collection systems

In countries where the commingled collection systems are well established, the domestic paper mills have to use more recovered paper from this source, which is a major challenge. For example, Aylesford newsprint mill in the United Kingdom use around a 10% of recovered paper from commingled collection systems and this is already a great achievement (White, 2007). If higher shares of recovered paper from commingled collection systems are used, the consequences on the process are very severe. Sacia and Simmons (2006), for example, described the case of a newsprint mill in the United States using ONP as raw material. When all the suppliers used source separated systems, unusable material content was a low as 0.25-0.50% with 0.0% non-paper components. However, when a 42% of the feedstock was sourced from commingled collection systems, the quality of the recovered paper decreased dramatically: 7.0% unusable material with 1.3% non-paper components (Table 5). This resulted in an 8-fold increase of pulper rejects (from 1% to more than 9%), a 4-fold increase in maintenance costs (mainly related to glass), a 57% increase of the level of stickies (requiring an additional US$2/ton for chemicals to deal with) and more than US$2.0 million to replace the lower content of fiber in the recovered paper due to yield loss. More recent data shows that the situation even becomes more difficult in this mill in the next years, when 68% of the feedstock was sourced from commingled systems and the unusable material content increased to 18.4% with 3.4% non-paper components (Table 5) (Contamination in Commingled Recycling Systems Standards & Guidelines Initiative, 2009). Some other examples of the consequences of the use of recovered paper from commingled collection systems can be found in CRI (2009), Emerson

(2004), Haynes et al. (2009), Kinsella (2006), Kinsella and Gleason (2003), Tucker (2007) and White (2007).

Table 5.- Effect of furnish sourcing on the quality of recovered paper of a newsprint paper mill. Source: Sacia and Simmons (2006); Contamination in Commingled Recycling Systems Standards & Guideline Initiative (2009).

Period	**Collection system**	**Total unusable materials (%)**	**Paper and board detrimental to production (%)**	**Non-paper components (%)**	**Glass (%)**
2001 and earlier	100% from source separated	0.25-0.5	0.25-0.5	0.0	0.0
Oct. 2003-Mar. 2005	42% from commingled	7.0	5.7	1.3	0.1
Sept. 2006-Dec. 2006	68% from commingled	18.4	15.0	3.4	0.33

The content of non-paper components is especially important when commingled collection systems are considered as their effect is more severe than paper and board detrimental to production. The percentage of non-paper components in unusable material content is always higher in the case of commingled systems than selective systems as cross contamination of the paper with other recyclables collected such as plastic, aluminium cans, etc., is always more likely. In selective collection methods, non-paper components represent around 5-15% of total unusable materials and the remaining 80-95% is paper and board detrimental to production (ASPAPEL and REPACAR, 2008; Bösner et al., 2008). Boards are the most important components of paper and board detrimental to production, either brown, grey or white boards, representing between 70% and 90% of total unusable materials (ASPAPEL and REPACAR, 2008; Bobu et al., 2010; Bösner et al., 2008).

However, in commingled collection systems, the non-paper components content is higher. During the present study, some selected samples were analyzed to determine the composition of unusable materials and, on average, around 30% were non-paper components (mainly cans, plastics, metals and textiles) and 70% paper and board detrimental to production (mainly brown and grey boards). These values are similar to other quality surveys of recovered paper from households (Haynes et al., 2009). The presence of glass is probably the most important consequence related to commingled collection systems. Glass affects operating costs of process by increasing the wear and tear rate of process equipment, maintenance costs, downtime, and safety risks. If levels of incoming glass exceed 0.5% the process could even be shut down (Sacia and Simmons, 2006).

In the countries where commingled collection systems are spreading, there is a real scarcity of recovered paper of a suitable quality, especially for graphic papers production. This makes necessary to import recovered paper from other countries without using commingled collection systems to have a raw material with quality enough for graphic paper production (Holland and Height, 2009; Marley, 2007b; WRAP, 2008). In these countries, at the same time, a high share of the recovered paper collected is exported, mainly to Asia, where collection systems are less developed and recovered paper is not enough to run the paper machines at 100% capacity. The scarcity of recovered paper is so large that they need to import recovered paper, often paying more than domestic markets and for lower quality materials such as the recovered paper from commingled collection systems (Holland and Height, 2009; Marley, 2007b; WRAP, 2008). They can use these low quality materials as the main grades produced are packaging grades, where the quality requirements are lower. However, as the rapid expansion of Chinese paper production begins to slow, they will supply more of their raw material needs from domestic collection and although they will still need to import significant quantities, quality is going to become one of the first criteria for deciding who they will buy from. Therefore, the United States and Europe will need to improve quality if they want to continue exporting to China.

4.3. Economy of commingled collection systems

Apart from all these detrimental effects on the manufacturing process, the better economics argued by the collection companies and municipalities is still being investigated and open to debate. At present, some studies are starting to show that this option could not be as economical as previously believed if total costs of collecting the recyclables, including sorting costs, are considered (CRI, 2009; Lantz, 2008). In 2008, WRAP published the results of a comprehensive study into different household recycling systems. The report found that in the current market, curbside sort schemes are more cost effective for Local Authorities than single-stream commingled, with two-stream commingled collections (where paper is kept separate) having similar net costs to curbside sort schemes (WRAP, 2008). Another report, prepared by Jaakko Pöyry and Skumatz Economic Research Associates for the AF&PA, estimated that if all dual-stream commingled systems were converted to single-stream commingled systems, the average decrease in collection costs for paper products would be offset by the increase in sorting and paper manufacturing costs, resulting in an overall net increase of about $3/ton (Table 6) (AF&PA, 2004). However, the conclusions obtained are still very different depending on the studies, even when they are referred to the same case such as the United Kingdom (see WYG Environment, 2012). Further economic analysis comparing commingled versus selective collection method can be found in CRI (2009).

Table 6.- Average cost differences by value chain segment when commingled collection systems are used. Source: AF&PA (2004).

	Collection	**Processing / Sorting**	**Pulping / Papermaking**	**Net increase**
Cost savings with commingled systems	$15 ($10-$20)			
Cost increase with commingled systems		$10 ($5-$15)	$8 ($5-$13)	$3 ($0-$8)

4.4. Legislative, private and public initiatives to limit spreading of commingled collection

In Europe, the threat of spreading the commingled collection systems has been partly minimized with the new Waste Directive (European Parliament and Council, 2008) as the selective collection of paper, metals, plastics and glass will become mandatory in all the EU members in 2015. However, there is still a great controversy in the United Kingdom, where commingled collection systems are more spread, as the authorities initially implemented the Waste Framework Directive understanding commingled collection as a form of separate collection. The initiative "Campaign for Real Recycling", a consortium of waste industry bodies and campaign organisations in the United Kingdom promoting selective collection against commingled collection systems (Miranda and Blanco, 2011), bring a call for a Judicial Review to avoid considering commingled collection systems as separate collection systems under the frame of Waste Directive; the Judicial Review has been adjourned twice, in December 2011 and June 2012. Recently, in June 2012, the European Comission has published the "Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste" which confirmed that, although not legally binding, commingled collections will be allowed under the Waste Framework Directive towards the requirement to introduce separate collection of paper, metals, glass and plastics by 2015.

In the United States there are also similar initiatives such as the "Contamination in Commingled Recycling Systems Standards & Guidelines Initiative" in the US EPA Region 10 (the Pacific Northwest), which have tried to improve the quality exiting at the MRFs by developing standards and guidelines for commingled recycling systems that will reduce cross-contamination of recycled materials, increasing the quality and quantity of materials recycled, and capturing the highest percentage of materials that are intended to be recycled.

5. CONCLUSIONS

The use of commingled collection systems has a severe effect on the quality of recovered paper for paper production. Total unusable material contents in the 10-15% range are common, extremely limiting the use of this raw material in the paper industry, especially for graphic paper production. In the analyzed mill, for example, the recovered paper from commingled collection systems is limited to around 4% of the feedstock. The mill would like to use more recovered paper from this source due to scarcity problems but it is not possible without affecting the process at the present quality level of the recovered paper, especially due to the presence of non-paper components (around 30% of total unusable materials).

In recent years, there has been an important debate about the convenience of commingled collection systems. It is usually argued that these systems render higher recovery rates at lower costs but the truth is that these systems yield a very low quality material, which cannot be fully exploited for graphic paper recycling, where the main potential for increasing the use of recovered paper in papermaking lies. New studies also argue that if all the costs along the paper recycling chain are considered, commingled collection systems could not be the most economic collection method as previously believed.

In the opinion of the authors, source segregation and separate collection are major pre-requisites for sustainable recycling. In Europe, new Waste Directive in Europe has partly minimized the threat of spreading the use of commingled collection systems to other countries in Europe and promoting the selective collection of all the recyclables, however, there is still a great controversy in the United Kingdom. The Directive is also expected to have an important influence on the quality of recovered paper available on the market through the “end-of-waste” criteria. Due to the potential benefits which can be expected by the recovered paper ceasing to be considered as waste (legal, economic, etc.), further efforts are expected along the recovered paper value chain to reduce total unusable materials to 1.5% or even less, the level required used paper ceasing to be a waste (Miranda et al., 2011; Villanueva and Eder, 2011).

Improvement of sorting techniques has demonstrated to have a strong influence on the quality of recovered paper: around 30% reduction on average unusable material content of the recovered paper (from 11.9% to 8.11%). These advances can improve the quality of the recovered paper collected by commingled collection systems. However, the threat of contamination with non-paper components is still higher than in the case of source separate methods due to cross contamination. Quality is probably the major prerequisite for extending the use of recovered paper as a raw material, especially in graphic paper production. Papermakers claims for source-separated collection systems to achieve the necessary recovered paper quality needed to make paper recycling a sustainable process.

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6. LITERATURE

AF&PA (American Forest & Paper Association). 2010 AF&PA Community Survey; 2011.

AF&PA (American Forest & Paper Association). Single-stream Recycling – Total Cost Analysis; 2004.

Anon. What next for paper? Declining export demand and concerns about quality and collection methods made for a gloomy atmosphere at a recent European Paper Recycling conference. Mater. Recycl. Week 2008;192(8):23-4.

ASPAPEL & REPACAR. Determination of the composition of materials and moisture content of recovered paper and board. Madrid (Spain): Prepared by NOVOTEC; 2008 [in Spanish].

Bösner, J.-K., Hirsch, G., Putz, H.-J., Weinert, S. Quality properties of the most important recovered paper grades in dependence of sorting conditions (AiF-Project 15408 N)". In: COST E48 Meeting; 2008 Sep. 13-15; Budapest, Hungary.

Bobu, E., Iosip, A., Ciolacu, F. Potential benefits of recovered paper sorting by advanced technology. Cellul. Chem. Technol. 2010;44(10):461-71.

Contamination in Commingled Recycling Systems Standards & Guidelines Initiative. Commingled Recycling Systems—Preventing Contamination at the Curb, Material Recovery Facility (MRF), and Mill; 2009. Available from: http://yosemite.epa.gov/r10/HOMEPAGE.NSF/Topics/ccrs [accessed April 2012].

CRI (Container Recycling Institute). Understanding economic and environmental impacts of single-stream collection systems. 2009. Prepared by Morawski, C. Available from: www.container-recycling.org/publications/ [accessed April 2012].

Emerson, D. Single stream vs source separated recycling. Biocycle 2004;45(3):22-5.

EN 643: European List of Standard Grades of Recovered Paper and Board. European Committee for Standardization. Brussels (Belgium); 2002.

CEPI (Confederation of European Paper Industries). 2011 Key Statistics. Brussels (Belgium); 2012.

European Parliament and Council, 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives. Official Journal of the European Union L312, 3-30 (22.11.2008).

Faul, A. Quality aspects of recovered paper for deinking. Prog. Pap. Recycl. 2005;15(1):6-10.

Faul, A. Quality requirements in graphic paper recycling. Cellul. Chem. Technol. 2010;44(10):451-60.

Haynes, R.D., Malloch, J., Cuddy, K., Nicodimos, E. Ask the recycle mil gals. Prog. Pap. Recycl. 2009;18(3):13-20.

Holland, T., Height, A. Recovered material quality is declining, says Aylesford newsprint. Recycl. & Waste Manage. News & Info. 03 July 2009.

Kinsella, S., Gleason, G. Single stream: An investigation into the interaction between single stream recycling collection systems and recycled paper manufacturing. Conservatree. United States; 2003.

Kinsella, S. Single-stream: closing the loop. Resour. Recycl. 2006;25(1):12-8.

Kinsella, S., Gertman, R. Single stream recycling best practices manual and implementation guide. Prog. Pap. Recycl. 2008;17(3):6-8.

Lantz, D. Mixed Results. Do the advantages of single-stream recycling hold up in a head-to-head comparison? An examination of several single-stream and dual-stream programs tell the tale. Resour. Recycl., Dec. 2008, 1-5.

Levlin, J.-E., Read, B., Grossmann, H., Hooimeijer, A., Ervasti, I., Lozo, B., Saint-Amand, F.J., Cochaux, A., Faul, A., Ringman, J., Stawicki, B., Bobu, E., Miranda, R., Blanco, A., Stanic, M. COST Action E48 - The future of paper recycling in Europe: opportunities and limitations. COST Office, Brussels (Belgium); 2010.

McClelland, S. Beyond the curb – tracking the commingled residential recyclables from Southwest WA. Department of Ecology of Washington State, publication no. 10-07-009; 2010.

Marley, M.E. The MRF as value factory and supplier of high quality paper. Pap. Technol. 2007a;48(6):2.

Marley, M.E. Quality the key issue facing the UK recovered paper sector. Pap. Technol. 2007b;48(6):3-5.

Miranda, R., Bobu, E., Grossmann, H., Stawicki, B., Blanco, A. Factors influencing a higher use of recovered paper in the European Paper Industry. Cellul. Chem. Technol. 2010;44(10):419-30.

Miranda, R., Blanco, A. Environmental awareness and paper recycling. Cellul. Chem. Technol. 2010;44(10):431-49.

Miranda, R., Monte, M.C., Blanco, A. Impact of increased collection rates and the use of commingled collection systems on the quality of recovered paper. Part 1: Increased collection rates. Waste Manage. 2011;31(11):2208-16.

Read, B. The future of recovered fibre in the UK. In: COST Action E48 Final Conference: The limits of paper recycling; 2009 May 6-7; Munich, Germany.

Sacia, W.K., Simmons, J. The effects of changing ONP quality on a newsprint mill. Tappi J. 2006;5(1):13-7.

Tucker, B. Paper recovery and challenges around the world. In: TAPPI 8th Forum on Recycling; 2007 Sep. 23-26; Ontario, Canada.

Villanueva, A., Eder, P. End-of-waste criteria for waste paper: technical proposals. Final report. Institute for Prospective Technological Studies, European Commission, Seville (Spain); 2011.

Wagner, J., Franke, T., Schabel, S. Automatic sorting of recovered paper – technical solutions and their limitations. Prog. Pap. Recycl. 2006;16(1):13-23.

Wagner, J., Franke, T., Schabel, S. Automatic sorting of recovered paper: technical solutions and their limitations. Rev. ATIP 2007;61(1):14-21.

White, C. Quality matters: the mill buyer's perspective. In: European Paper Recycling Conference; 2007 Oct. 3-5; Amsterdam, The Netherlands.

WRAP (The Waste and Resources Action Programme). Optimising the value of recovered fibre. Oxon (United Kingdom); 2004

WRAP (The Waste and Resources Action Programme). Materials Recovery Facilities. Oxon (United Kingdom); 2006.

WRAP (The Waste and Resources Action Programme). Recovering value from MRFs. A review of key studies relating to the specification, operation and costs of Materials Recovery Facilities. Oxon (United Kingdom); 2007.

WRAP (The Waste and Resources Action Programme). Kerbside Recycling: Indicative Costs and Performance. Oxon (United Kingdom); 2008.

WRAP (The Waste and Resources Action Programme). Market Situation Report – Winter 2009/10. Realising the value of recovered paper: an update. Oxon (United Kingdom); 2010.

WYG Environment. Review of kerbside recycling collection schemes in the UK in 2010/11. Leeds (United Kingdom); 2012.