

SUSTAINABLE PRINTING GOES FAR BEYOND USING FSC-CERTIFIED OR RECYCLED PAPER

Informative paper on deinking:
demand, principles, problems,
and solutions.

IN THIS PAPER

This paper discusses current and future demand for paper and explains why recycled paper is needed. It also explains why printing technologies are not all equally compatible with paper recycling systems, and why just a small fraction of this printed material in the paper load can cause a great many difficulties.

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PAPER DEMAND OVER THE NEXT FEW YEARS

The graphs on this page shows that current global market demand for paper material exceeds 400 million metric tons, 50% of which is white paper-based material.

Roughly 20% of paper is needed in Europe, 20% in North America, 50% in Asia, and the rest is used in South America and Oceania. Due to the high demand for paper materials, collection and recycling is mandatory since there are just not enough trees in the world to meet the yearly demand. Packaging materials are mostly recycled within their category. Graphic paper is deinked and recycled for new use in graphic paper and tissue applications.

Based on these data, the entire paper recycling industry is seeking to ensure that paper can be used as many times as possible in order to guarantee that enough paper is available to meet demand at affordable prices. A major threat to the paper recycling industry may therefore be if existing or new printing technologies were to be used that might reduce efficiency or yield in the paper recycling process. This would not only be detrimental to the recycling business but could also result in an inability to provide the paper material needed locally or globally.

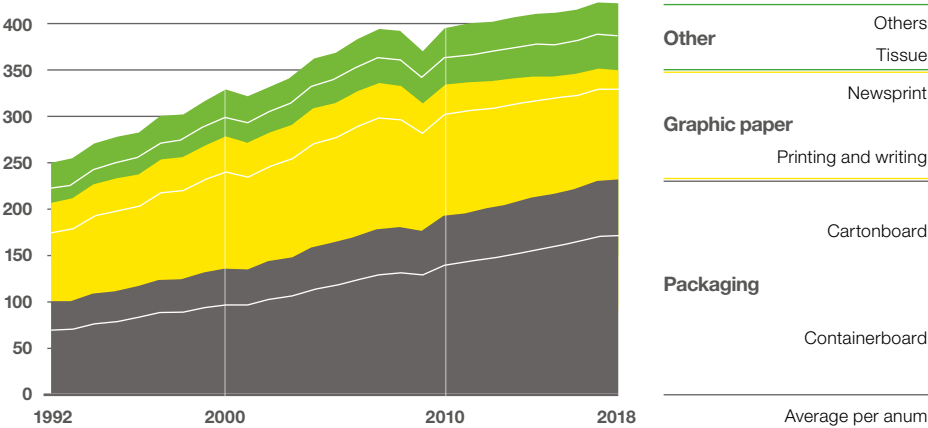


Figure 1: Global paper and paperboard market in million metric tons (Source: Resource Information Systems Inc. – RISI February 2019)

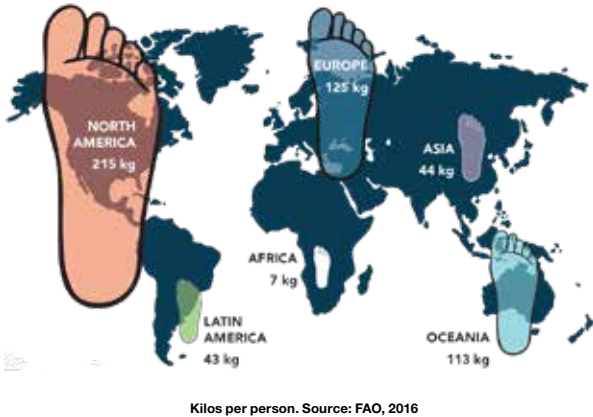
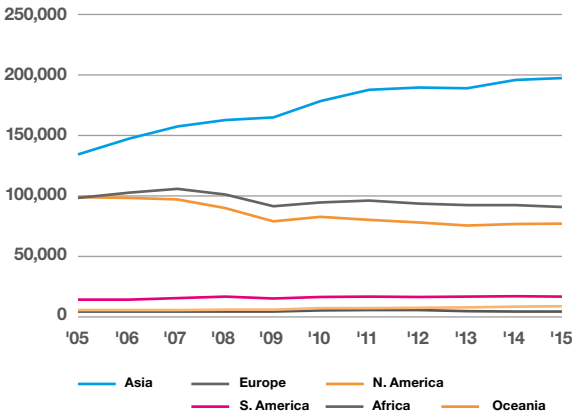


Figure 2:
Right: Paper consumption by region (2005-2015).
Left: Paper consumption per capita – source FAO – The Food and Agriculture Organization of the UN

PAPER RECYCLING FACTS

The recycling rate in Europe was 72% in 2019, which is already quite high. In theory, however, the maximum collection efficiency could be 81% since the proportion of non-collectable and non-recyclable paper is estimated to be 19%. This type of paper cannot be recycled or collected for technical reasons (library books, archives, sanitary paper, etc.).

While Europe performed well in 2019 (72%), we can see that Japan is doing even better, almost reaching the figure of 81% (see Figure 4).

European recycling 1991-2019

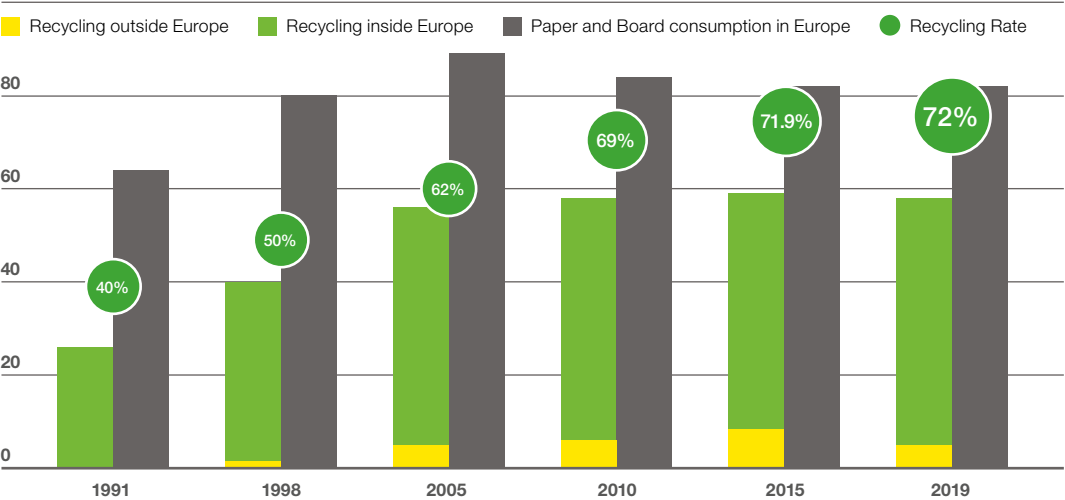


Figure 3:
European recycling versus consumption in the period 1991-2019 (Source: CEPI 2019)

Paper recovery trend Japan

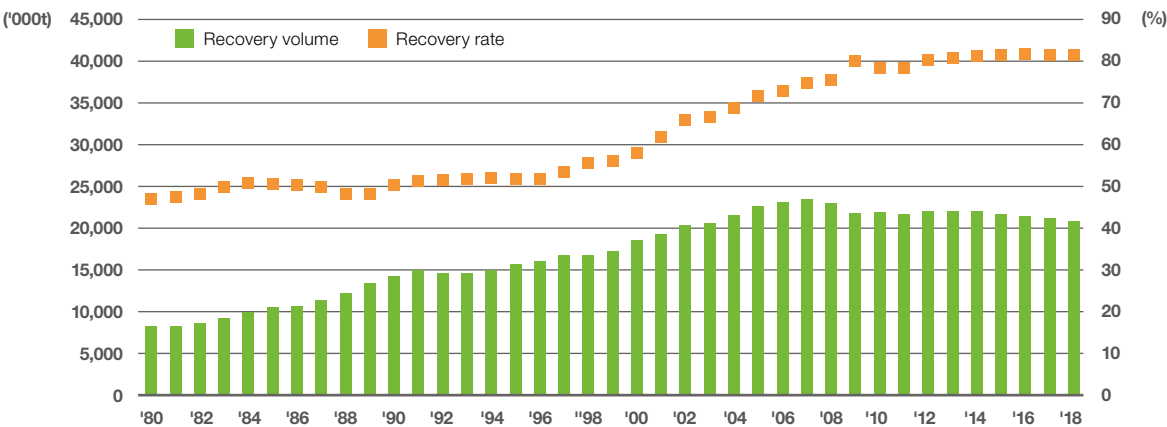


Figure 4:
Trend in paper recovery (metric tons in green, recovery rate in orange) in Japan (<http://www.prpc.or.jp/wp-content/uploads/PAPER-RECYCLING-IN-JAPAN-2019.8.pdf>)

How does paper recycling work?

In the first step of the deinking process, paper is mixed with water and some detergent and mechanical energy is applied to make a paper pulp with a slightly increased pH (8-9).

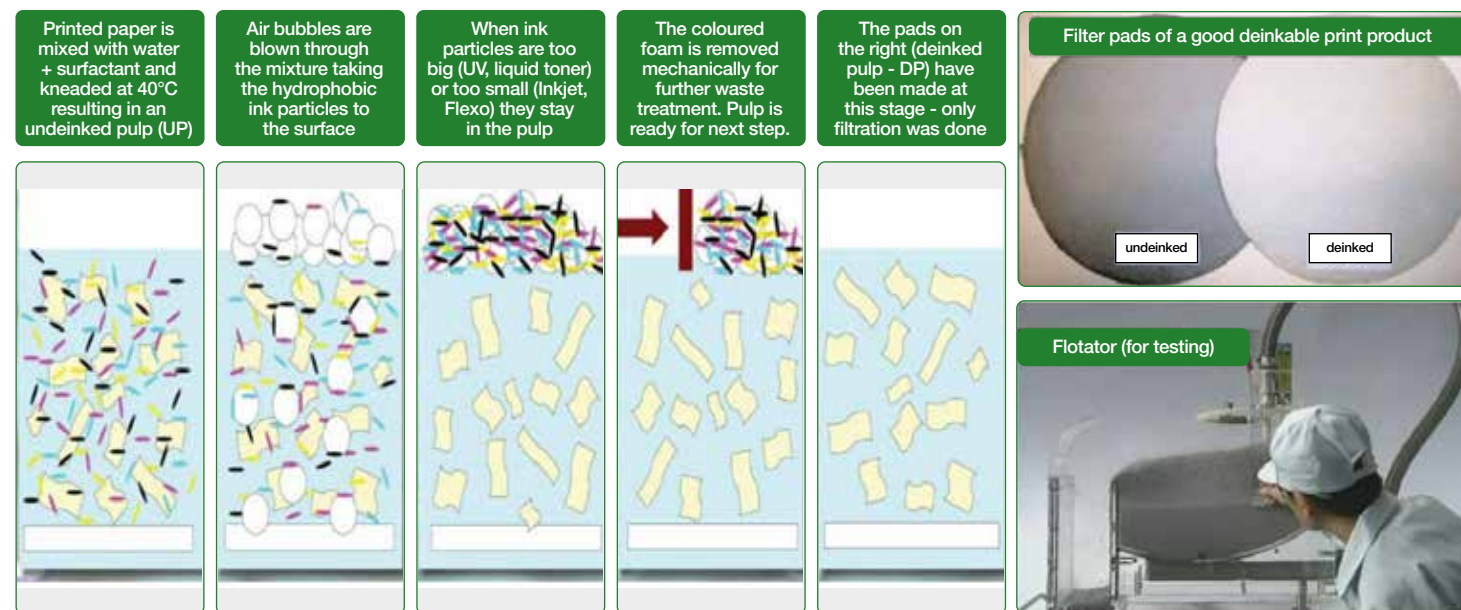
This mechanical action (called pulping) is crucial because it breaks down the ink material into smaller particles.

The next step consists of blowing small air bubbles through the pulp mixture (flotation).

Based on the fact that the hydrophobic ink particles like the air interface more than the water phase, this action causes the colored ink particles to float to the surface, separating from the pulp mixture and forming a grey foam that is then skimmed off.

The end result is pure white paper pulp, which can be used to make new paper. This process works perfectly with a lot of inks and is well established in all paper recycling plants around the world.

Figure 5:
Principle of deinking/
flotation explained.
Upper right:
Paper pulp before and
after flotation (if all
goes well).
Lower right:
Lab flotation cell to
test the deinkability of
paper/ink



INGEDE method 11

INGEDE is the International Association of the Deinking Industry (www.ingede.de). Its aim is to guarantee the quality of incoming materials to ensure it is compatible with the industry's investments and the processes in place. INGEDE has therefore developed methods (e.g. test methods 11 and 12) to test the deinkability of printed materials in the lab and

assign them a score. This score is explained in detail at <https://www.paperforrecycling.eu/download/882/> and comprises several aspects that are evaluated (paper whiteness, specks, filtrate darkening, yield, etc.). All the part-scores are added together to produce the final deinkability score. Xeikon toners always score more than 90!

Score	Evaluation of removability
71 to 100 Points	Good
71 to 100 Points	Fair
71 to 100 Points	Tolerable
Negative (failed to meet the threshold)	Insufficient

Figure 6: Table of deinking scores. If one parameter is not within normal range, the material fails the test, and the score is negative.

MOST DRY TONERS ARE OK!

Dry toners are made from polymers and pigments.

Dry toners are made from polymers and pigments. These polymers are specially selected to ensure the pigments adhere very well to the paper surface after the fusing step. In most cases, they are also selected and specially designed to have a certain degree of brittleness. This brittleness is used during toner manufacturing, where the polymer particles are accelerated above the speed of sound and collided into each other. During this collision, the particle size is reduced, and particles of the right size and shape are subsequently used in the toner-making process. It is important to mention here that a new technology for making toners (starting in a chemical reactor where the particles are “grown” in a liquid phase) results in a toner system that is less brittle and can cause some issues with the flotation/deinking process described above.

In the pulping phase of the deinking process, these same toner particles are again reduced in size mechanically and have the right hydrophobicity to be removed from the paper

fibers. All current Xeikon toners (FA, QA, and QB systems) comply 100% with this process, resulting in perfect deinkability.

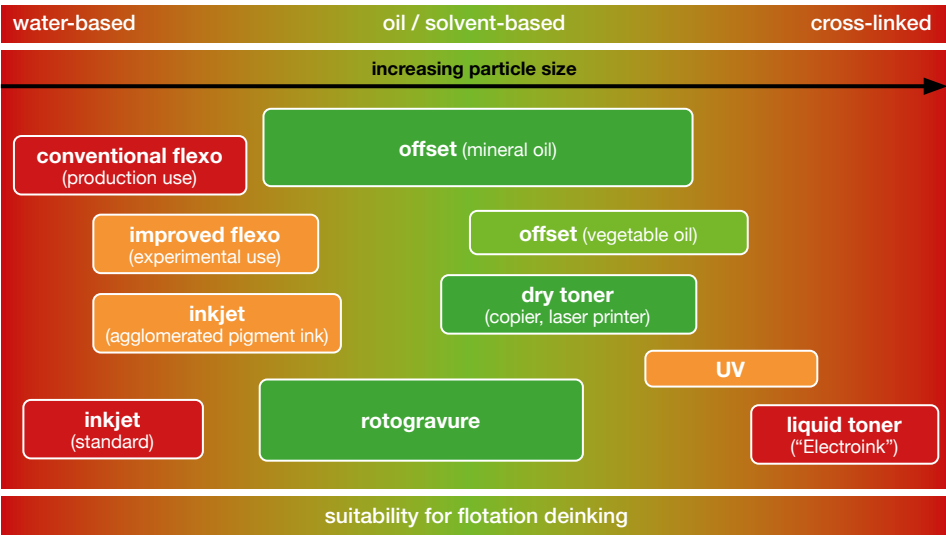
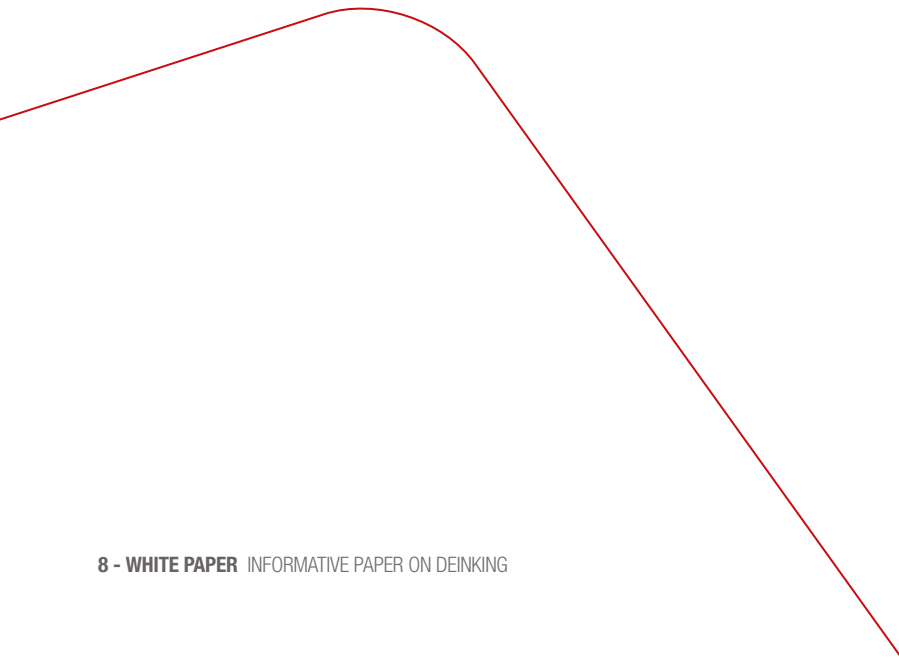


Figure 7: Deinking of the different ink types used for printing on white paper that needs to be deinked, and how they rate in terms of deinkability (Source: INGEDE)

When can it go wrong?



In some cases, the deinking process encounters a great many difficulties or becomes impossible to perform.

The first is flexo newspaper printing. The inks used here are water soluble, so they do not tend to go into the air phase, as they are perfectly happy in water. This results in a darkening of the paper pulp, yielding a lower grade of paper. To prevent this happening, flexo-printed newspapers are collected separately from other paper waste in Italy and the UK. This is possible because people in these countries know the difference between newspaper and other printed material and are aware they have to keep this paper separate based on the easy distinction: newspaper – not newspaper.

Water-based inkjet printed material suffers from the same problem: the colorants (dyes or pigments) have an affinity for the water phase and therefore remain in the pulp. Where pigments are used, there is no way to remedy this – these colorants are designed to be lightfast and cannot be bleached even in special plants that have bleaching equipment.

Section 04

BINDING AGENTS - PRIMERS?

Fortunately, there are a few prototypes of new pigmented inks that can “coagulate” (stick together) after printing to form larger aggregates. These are hydrophobic enough to be removed and carried to the surface by the bubbles (“taking the air taxi to the surface”). However, for dye-based inkjet inks no solution is in sight.

The crucial problem is that neither users nor sorting plants can differentiate between offset, dye-pigmented inkjet and dry/liquid toner-based printing, so in these cases it is not possible to remove prints made using dye-based inkjet inks from the regular waste stream (unless they are clearly marked...).

Inkjet manufacturers, pigment providers, paper makers, and deinking chemical suppliers are working hard to solve this issue by using special coated paper or special agents during printing that make the pigments stick together and, therefore, water insoluble. This helps in removing the ink particles during the flotation step. They only have to ensure that this coagulation on top of the paper surface is sufficiently irreversible so that the agglomerates do not become soluble again in the pulping phase. This is crucial for this technology and most of the current inkjet inks are not capable of performing this irreversible coagulation action.

The scientific explanation for this is as follows. The surface of the pigment particles is made hydrophilic by adhesion of specially designed polymeric molecules, one side of which absorbs onto the pigment surface, with another part remaining in the water phase.

These water phase portions consist mainly of carboxylic groups that are deprotonated to increase the polarity of the pigment and hence the hydrophilicity.

The addition of some metallic ions on the paper surface while manufacturing the paper (Colorlok) helps to improve image quality but does not improve deinkability. Applica-

tion of calcium salts through a colorless ink or a pre-coating/primer just prior to printing creates insoluble calcium carboxylates that change the nature of the pigment from hydrophilic to hydrophobic. These pigment clusters can be much more easily removed using common deinking procedures (the so-called inkjet agglomerated pigment inks in Figure 9).

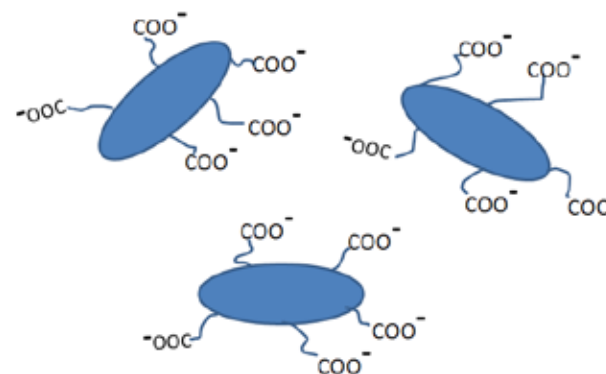


Figure 8: Pigment particles made hydrophilic in order to have good compatibility with water

Does this solve the problem?

Not in every case.

Not in every case. In the early days of inkjet, an attempt was made to jet a calcium solution through a fifth row of print heads to allow instantaneous coagulation on the paper. However... these calcium ions also tend to react with carbon dioxide in the atmosphere, forming insoluble calcium carbonate salts. These insoluble crystals can block the nozzles if the agent is jetted via an inkjet system.

To prevent this happening, some manufacturers have replaced the solution containing

calcium ions with an acidic solution. This has the same effect during printing: it keeps the pigments on the surface of the paper, avoids penetration of the color through the paper, creating ghost images on the back, and gives better color strength. Unfortunately, this process is reversible under the alkaline conditions of the deinking process and the carboxylic acids are again deprotonated during the pulping phase of the paper recycling process, with zero net improvement in terms of deinking.

The only successful way to improve both image quality and deinkability by adding calcium ions is to fully coat the paper with a roller immediately before printing. This allows the wet-in-wet diffusion of particles towards each other, forming larger aggregates that are hydrophobic and stable enough to float with the bubbles.

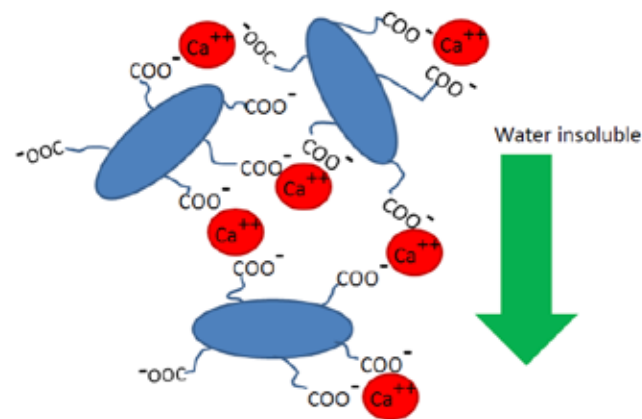


Figure 9: Pigments are made insoluble by interaction with calcium ions and are precipitated onto the surface of the paper

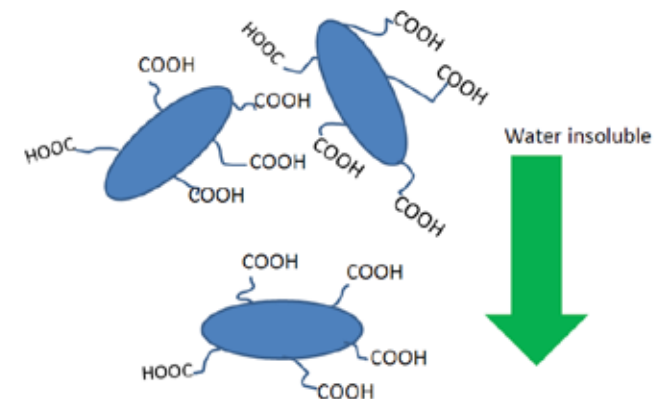


Figure 10: Pigments made insoluble by lowering the pH (or increasing the acidity) of the paper surface – this is more reversible than the complex formation shown in Figure 9

CHEMICAL TONER

As mentioned above, the use of chemical toner can have certain advantages, for instance in terms of a lower degree of fusing, better scratch resistance, and less complex printers. But it can also result in “not so good” deinkability. The toner particles no longer need to be brittle, which has an impact in the pulping phase, where the printed resin layers are not reduced to a small enough size to guarantee good flotation. If the particles are too large, they are too heavy to end up in the foam layer that has to be skimmed off.

VEGETABLE OIL-BASED OFFSET INKS

This is a peculiar one. In order to reduce the contamination of mineral oils, ink manufacturers have switched over massively to more sustainable vegetable oils. But since these oils have – in many cases – unsaturated moieties in their chemical structure, they can crosslink with oxygen, creating film structures that are much more difficult to break apart and deink. This is an example of how a more sustainable (and non-petroleum-based) approach can affect another crucial sustainability aspect – recycling. Life isn't easy!



Section 05

LIQUID TONER AND UV INKS

Other types of inks that create these kinds of problems to a much greater degree during the deinking process are UV-cured inks or “good” inks that have received a UV-cured lacquer or varnish. UV flexo, UV offset or UV inkjet all pose serious challenges. The same is true for liquid toner (such as “ElectroInk”). Each of these inks forms a flexible polymer film on paper that behaves totally differently than other inks. Here, again, the problem is remaining in the water phase, because the ink film cannot be broken up into smaller particles – the large, thin, and, in the case of liquid toner, very flexible polymer film pieces slip through the screens intended to separate larger impurities from the thin fibers. In the flotation process, the large particles are too heavy (and not hydrophobic enough) to

be carried to the surface by the air bubbles, so they stay in the water phase with the fibers. This results in large visible specks exceeding the specifications of high-grade white paper or sanitary paper.

Making changes in the deinking process (e.g. implementing double flotation and dispersion) reduces the number of these specks but, especially in the case of ElectroInk, this is still not enough to obtain the desired degree of whiteness and speck-free recycled paper.

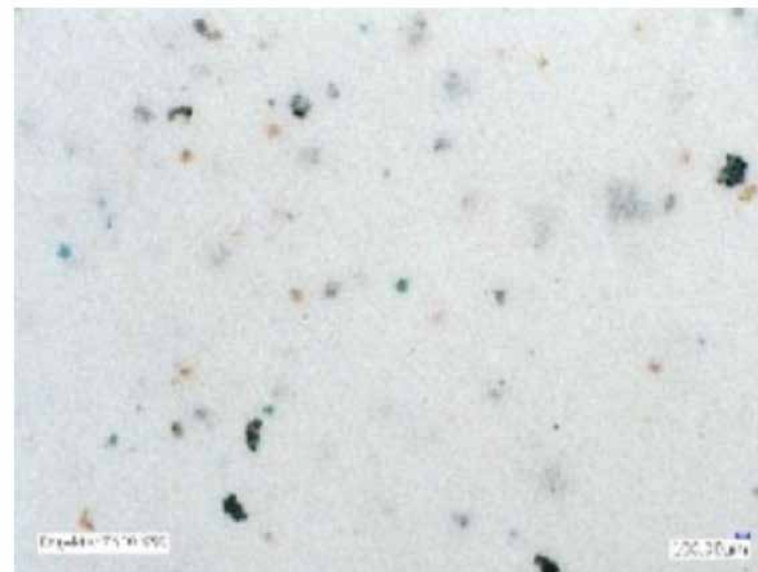


Figure 11: Dirt specks after the flotation process of a non-deinkable ink

Section 06

WHAT ABOUT THE UNITED STATES?

Deinking plants in the US work in the same way as European ones, but there are some differences.

The first difference is the amount of recycled fiber used in the US process. The collection rate in the US is approximately 20% lower than the EU average (53.4% in the US compared with 72.3% in the EU for 2009). This results in US plants using more white virgin fiber at the end of their recycling process to make recycled paper.

Additionally, when the whiteness of the paper is not high enough, it is standard practice in US recycling plants to give the fibers an extra rinse. As a result, efficiency and yield are reduced and much more wastewater has to be treated or discharged into waterways.

EU recycling plants do treat all their wastewater and are extremely yield-sensitive. This explains why European deinking plants are much more sensitive to potential upcoming problems in the field of paper recycling. But if demand for paper continues to grow and the supply of trees becomes limited, non-EU deinking plants will also have to ensure that their recycling process uses less water and less energy and produces higher yield.



CONCLUSIONS

Not all printing technologies are equal in terms of their deinkability or paper recyclability behavior. The problem was brought to the attention of the paper industry after a few incidents with UV-offset printed material and some liquid toner prints. Additionally, European paper plants have noticed a constant overall decrease in whiteness of the deinked paper they are able to obtain, certainly since some paper-deinking plants do not want to or simply cannot add fresh fiber. Part of this decline has been linked to the small amount of inkjet material that is contaminating the larger, non-problematic quantities of printed paper. The actual amount of inkjet material (estimated at a total of less than 1% of the “white” paper material recovered in the EU) is now already posing serious challenges at the mills.

All these facts together – the difficulty of identifying types of paper that can cause problems, the need to increase the amount of recycling in view of growing paper demand, and the difficulty of adapting deinking equipment (if that would help at all) – sum up the paper industry’s very cautious attitude towards increased quantities of inkjet, UV and ElectroInk-printed paper being presented at their mills.

The first step could be to introduce a clear mark, indicating that the printed items can be recycled. This is also why sustainability labels like Blue Angel, Swan, Umweltzeichen, etc. all require good deinkability scores for printed material in order to allow their labels to be used.

Fortunately, dry toner-based printed material does not give rise to any of these problems. These prints have been around for more than 50 years and represent approximately 5-10% of the total quantity of printed white paper material. They have always been mostly recyclable at paper plants without any additional costs and without requiring any special paper substrate or modification of the toner systems or the printing press.

From an economic point of view, paper recycling is a vital necessity, since recycling uses two-thirds less water and energy – and the supply of fresh paper fiber would be insufficient to meet demand if recycling were to be shut down today. With new printing technologies being introduced and used that could jeopardize the current processes, this would mean that white paper would become more expensive or graphic paper would be less white.

Printing companies and printing equipment suppliers should therefore be aware that the more non-recyclable paper they print (or that is printed using their technology), the more the paper recycling plants will have difficulty being sustainable in an economically responsible way. Paper recycling companies are already struggling to cope with the very small amount of inkjet-printed paper that is getting into the paper stream from, for example, households, offices, and schools. In recent years they have had to expend more and more effort at increasing cost to process the incoming mix in order to achieve the desired whiteness, even though inkjet paper represents only a very small fraction of the total quantity of printed paper received. Imagine how wor-



“Sawing the branch off the tree you’re sitting on is never a good way to move forward...”

Dr. Lode Deprez, Xeikon

ried the paper recycling industry is at the moment, knowing that this fraction is going to increase significantly (e.g. by printing newspapers using inkjet instead of offset or switching a large proportion of advertising and mailing material from offset to inkjet – all very short-lived printed material)!

Sawing the branch off the tree you’re sitting on is never a good way to move forward...

Dr. Lode Deprez

VP Digital inks and Imaging Processes, RA and IP, Xeikon

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ABOUT XEIKON

Xeikon is an innovator in digital printing technology. The company designs, develops and delivers web-fed digital color presses for label and packaging applications, document printing, as well as commercial printing. These presses utilize LED-array-based dry toner electrophotography, open workflow software and application-specific toners. Xeikon also manufactures basysPrint computer-to-plate (CtP) solutions for the commercial printing market. These proven CtP systems combine the latest exposure techniques with cost-efficient UV plate technology, high imaging quality and flexibility. For the flexographic market, Xeikon offers digital platemaking systems under the

ThermoFlexX brand name. ThermoFlexX systems provide high resolution plate exposure including screening, color management, as well as workflow management. All the Xeikon solutions are designed with the overarching principles of profitability, quality, flexibility and sustainability in mind. With these guiding principles and a deep, intimate knowledge of its customers, Xeikon continues to be one of the industry's leading innovators of products and solutions.

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