Effect of poorly deinkable paper on deinked pulp quality

GEORG HIRSCH, DENNIS VOSS, HANS-JOACHIM PUTZ, AND SAMUEL SCHABEL

ABSTRACT: Laboratory tests were performed to assess the influence of various digital prints and packaging paper products on the quality of deinked pulp. Boards and digital prints were dosed to a certain percentage in basic mixtures of offset printed newspapers and offset and rotogravure printed magazines. After pulping, the fiber suspensions were treated in a single step flotation process and the deinked pulp was characterized by optical properties. Effects on optical properties of deinked pulp are presented.

Each proportion of 4% corrugated board in a basic mixture of recovered paper results in a 1 point loss in luminosity of the deinked pulp. The luminosity decrease corresponds with increasing degree of printing ink on the board. With increasing proportions of corrugated board, a shift in the color locus and increased filtrate darkening were observed, simultaneously. All effects were smaller for boxboard than for corrugated board.

The negative impact of digital prints in a basic recovered paper mixture in terms of luminosity of deinked pulp was greatest with inkjet printed newspapers. A proportion of 30% inkjet printed newsprint results in a luminosity drop of almost 7 points, combined with a shift of the color locus into the green area. Regarding liquid toner prints in the basic mixture of recovered paper, a significant increase of the total dirt speck area from 200 mm^2/m^2 to 1100 mm^2/m^2 was observed after a single laboratory flotation process.

Application: Mills can identify which paper products to avoid for the benefit of better deinked pulp quality.

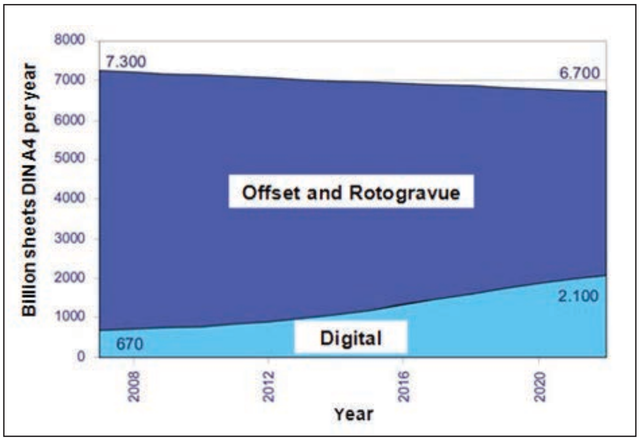
In Europe the EN 643 [1], a standard list of recovered paper grades, is the basis for common trade of recovered paper. According to this list, several recovered paper grades are useful for deinking purposes, but grade 1.11—sorted graphic paper for deinking—is the most relevant. Typically, it is generated by household collections and comprises good and non- or poorly deinkable paper products and packaging materials, even after careful sorting. The specification for grade 1.11 limits the content of nondeinkable material to 1.5%. Nondeinkable material includes graphic paper products, such as flexo or inkjet printed newspapers, as well as packaging material, such as corrugated board and boxboard.

In reality, grade 1.11 contains more than 1.5% nondeinkable material. An investigation of the composition of several recovered paper grades in Germany showed that grade 1.11 comprises, on average, 6.3% of dyed paper, wallpaper, hygienic paper, and board. The 6.3% was mainly corrugated board and boxboard. Print products, such as inkjet and flexo printed newspapers, are not included in the 6.3% [2]. Investigations on grade 1.11 from various European countries showed the proportion of nondeinkable material to be between 2% to almost 14%; the typical range is 3%-8% [3,4]. Because paper mills have to handle recovered paper with higher amounts of undesired paper products, the stock preparation plants of the mills are usually adequately equipped.

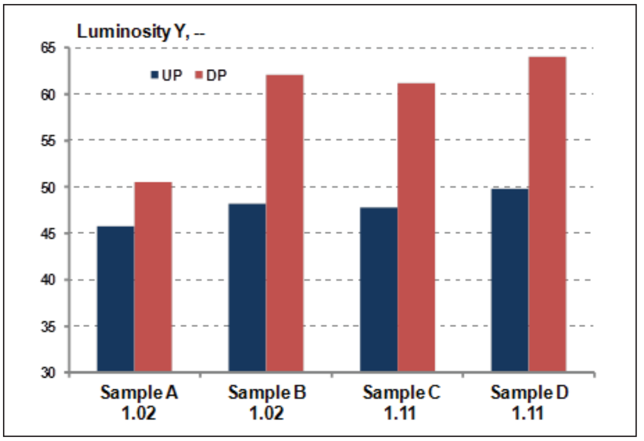
The nondeinkable paper products introduced with the recovered paper mixture in the paper mills vary in their composition and probably in their deinking behavior. Even if there is a lot of knowledge about the behavior of single print products during laboratory flotation deinking under standard conditions [5-7], during modified flotation chemistry [8-15], or during physical pulping or flotation conditions [16-24], there is insufficient knowledge about the effect of digital printed paper products and different packaging material as a proportion of a recovered paper mixture on optical paper properties after flotation This knowledge, however, is needed to characterize the requirements of deinking plants treating recovered paper for deinking. Even when the results are related to typical European recovered paper mixtures, the results of the unwanted material can be easily transferred to other recovered paper mixtures for deinking.

The market share of digital printed products will increase in the future, as **Fig. 1** shows. Flexible print processes and personalized print products with digital printing technologies manage quite well the balance between cost-effectiveness, low and medium circulation, and print quality [25-27]. Therefore, paper mills have to expect that the content of products printed using inkjet, dry toner, or liquid toner (LEP) processes will rise in the recovered paper for deinking.

First deinking investigations at the the Paper Technology and Mechanical Process Engineering (PMV) laboratory at the



1. Development of the printing volume of offset, rotogravure, and digital printing in North America and Western Europe.



2. Luminosity (Y) before and after flotation of two samples of grade 1.02 and two samples of grade 1.11 papers.

Technische Universität Darmstadt (Darmstadt, Germany) have shown that grade 1.02 recovered paper (mixed papers and boards [sorted]), which contains 13% packaging papers (sample B), can reach similar deinking results as grade 1.11 recovered paper (samples C and D), as **Fig. 2** shows. All four samples were deinked in a single loop deinking process according to INGEDE Method 11 "Assessment of print product recyclability—deinking test."

To characterize the requirements on the composition of recovered paper grade 1.11, to be prepared for the changes in the composition, or to open up a new resource for standard newsprint, knowledge is needed about the influence of board and digital print products on the deinkability of recovered paper mixtures. However, the behavior of single board types and digital print products in a mixture is almost unknown. Only a few publications exist in which the recovered paper mixtures to be deinked were varied systematically regarding proportion of nondeinkable print products and packaging materials [28-30]. This investigation was undertaken to close this knowledge gap.

MATERIALS AND METHODS

In this paper the influence of six and three types of corrugated boards and boxboards, respectively, is presented. Details about packaging materials are summarized in **Tables I** and **II**.

Each board was dosed to a basis mixture of print products consisting of 50% offset printed newspapers, 25% offset printed magazines, and 25% rotogravure printed magazines. Three proportions of each packaging material were added: 3%, 6%, and 12%.

To examine the influence of digital print products, an inkjet printed newspaper and stationery prints on woodfree paper with luminosity higher than 75% of dry toner printing, LEP printing, and inkjet printing were considered. Also, these print products were dosed to a basis mixture of 50%

Code	Top Ply	Liner	Fluting	Printing Technique	Degree of Printing
CB 1	Brown	Kraftliner	Recovered paper based fluting	Flexo	Low
CB 2	White	Kraftliner	Recovered paper based fluting	Flexo	High
CB 3	Brown	Kraftliner and testliner	Recovered paper based fluting	Flexo	Low
CB 4	White	Kraftliner and testliner	Recovered paper based fluting	Flexo	Medium to high
CB 5	Brown	Testliner	Recovered paper based fluting	Flexo	Low
CB 6	White	Testliner	Recovered paper based fluting	Flexo	Medium

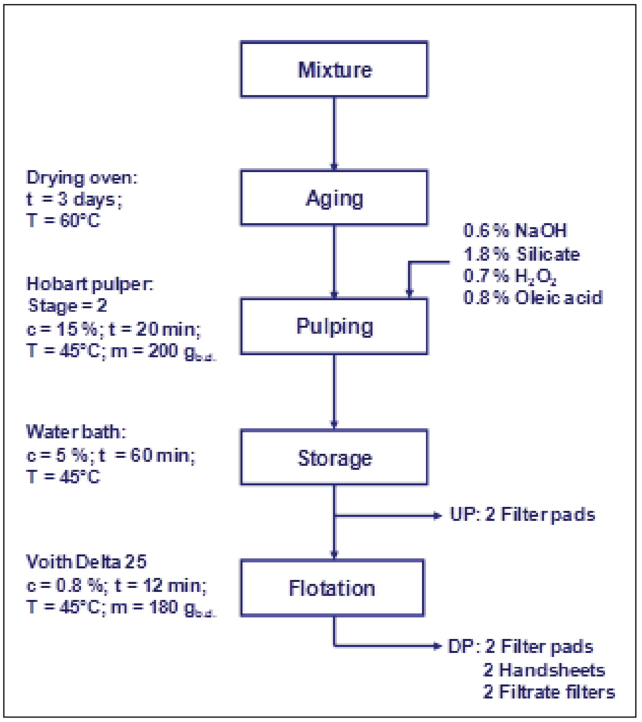
I. Details of the six corrugated boards.

Code	Type	Printing Technique	Degree of Printing
BB 1	Chipboard	Offset	Low
BB 2	Coated folding boxboard	Offset	*High*
BB 3	Coated white-lined chipboard	Offset	High

II. Details of the three folding boxboards.

offset printed newspapers, 30% offset printed magazines, and 20% rotogravure printed magazines. Because the influence of print products was investigated, offset printed newspapers in the mixture were replaced by inkjet printed newspapers and offset printed magazines were replaced by LEP, inkjet, and dry toner printed stationery. Of all four digital print products, two proportions were realized; the low proportion was 15% and the high proportion was 30%. An overview of the composition of the examined mixtures is shown in **Table III**.

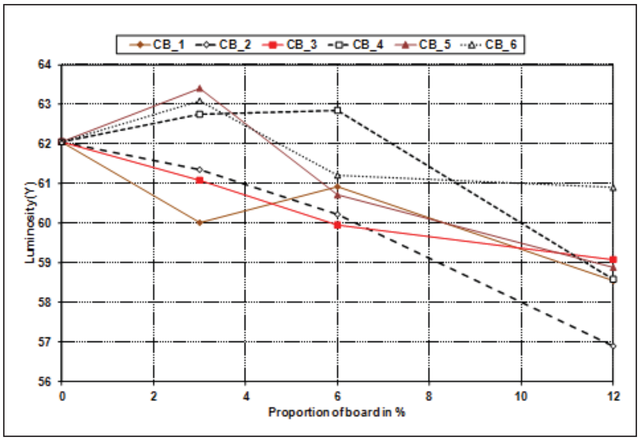
The recovered paper mixtures with board, as well as the mixtures with digital print products, were treated according to INGEDE Method 11. As sole variation to INGEDE Method 11, the pH value was not corrected but only measured. **Figure 3** shows the procedure for the method. The filter pads, handsheets, and filtrates were optically measured and evaluated. All recovered paper mixtures were analyzed for luminosity (Y), color locus (a* and *b), dirt speck area (A_{50} and A_{250}), and filtrate darkening (ΔY). The mixtures with board were also investigated for colored fibers, which were measured with a DOMAS image analysis tool (PTS; Munich, Germany). The mixtures with digital prints were also investigated for ink elimination (IE_{700}); because unprinted stationery paper has



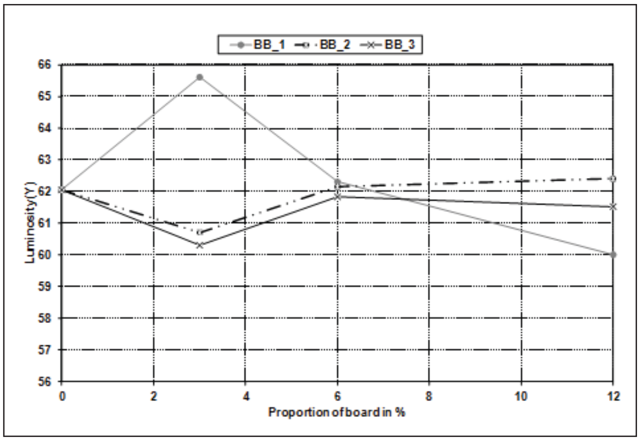
3. Procedure for INGEDE Method 11.

Print Product	Basis	Inkjet		Stationery					
		NP 15	NP 30	Liquid Toner 15	Liquid Toner 30	Inkjet 15	Inkjet 30	Dry Toner 15	Dry Toner 30
Offest printed newspaper	50	35	20	50	50	50	50	50	50
Offset printed magazine	30	30	30	30	15	30	15	30	15
Rotogravure printed magazine	20	20	20	5	5	5	5	5	5
Inkjet printed newspaper		15	30						
LEP printed stationery				15	30				
Inkjet printed stationery						15	30		
Dry toner printed stationery								15	30

III. Composition of the examined mixtures containing digital prints, by percentages in mixture.



4. Change in luminosity depending on the proportion of corrugated board in the recovered paper mixture.



5. Change in luminosity depending on proportion of boxboard in the recovered paper mixture.

high luminosity, only considering luminosity values could lead to a wrong interpretation of the deinking results.

DEINKING RESULTS OF THE MIXTURES WITH BOARD

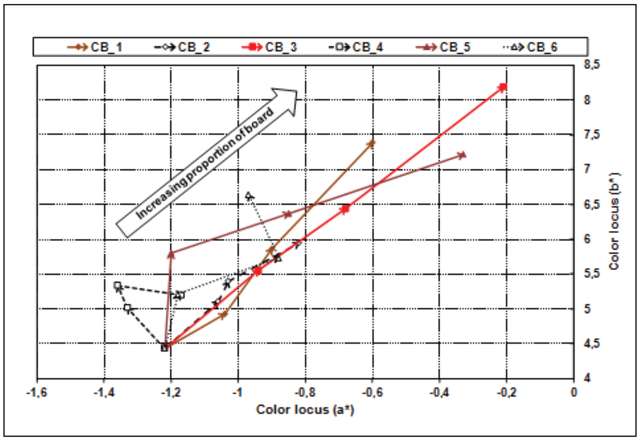
Figures 4 and **5** show the changes in luminosity of the deinked pulp depending on the proportion of corrugated board (CB) or boxboard (BB) in the recovered paper mixture. The brown corrugated boards (CB 1, CB 3, and CB 5) cause similar loss independent of the liner material. These three boards had a similar low degree of printing. The three white-lined corrugated boards (CB 2, CB 4, and CB 6) cause different luminosity losses that correlate with the degree of printing. The lowest degree of printing and lowest luminosity loss was seen with CB 6 and the highest printing degree and highest luminosity loss was seen with CB 2. A proportion of 4% corrugated board creates a 1 point loss in luminosity, on average.

The three boxboards (BB 1, BB 2, and BB 3) show almost no influence on the luminosity of the deinked pulp except the 3% and 12% dosage of BB 1. At the 3% dosage point of BB 1, a clear increase in luminosity is visible. At 12% content the luminosity decreases.

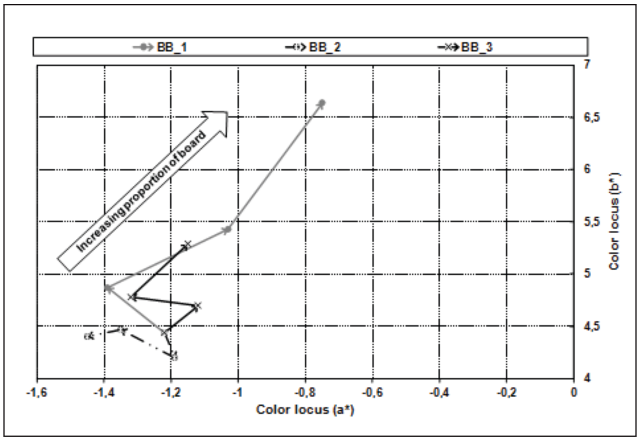
Changes in a* and b* values are displayed in **Fig. 6** for corrugated board and in **Fig. 7** for boxboard. The deinked pulp of mixtures with corrugated board has a clear shift of the a* value to red and of the b* value to yellow. This shift is highest for the three brown corrugated boards (CB 1, CB 3, and CB 5) but also is clearly visible for the three white-lined corrugated boards (CB 2, CB 4, and CB 6). The largest shift is caused by CB 3, which contains kraftliner as well as testliner.

Figure 7 shows that the three boxboards do not exhibit such an extreme shift as the brown corrugated boards; the shift is similar to the white-lined corrugated boards. Just the chipboard (BB 1) causes a clear change of the a* value to red and of the b* value to yellow.

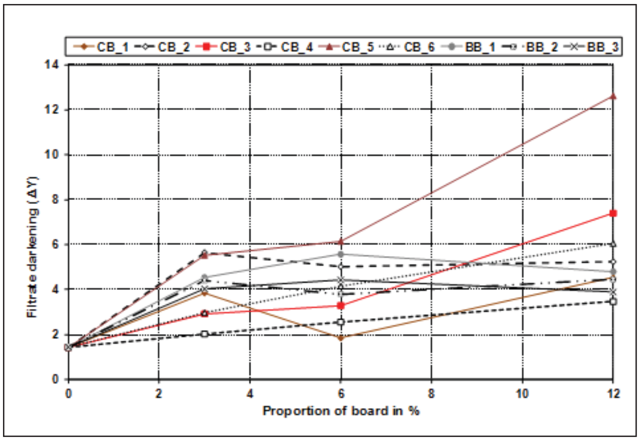
The filtrate darkening (ΔY) represents the discoloration of the process water by very small ink particles or dyes. It rises with increasing proportion of corrugated board and boxboard in a recovered paper mixture, as **Fig. 8** shows. The rise is between 2 and 6 points for eight of the nine investigated boards when 12% board is in the mixture. With a pro-



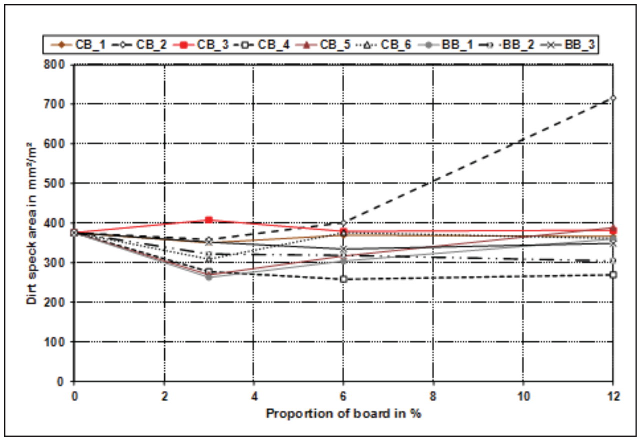
6. Change of color locus a and b* depending on proportion of corrugated board in the recovered paper mixture.*



7. Change of color locus a and b* depending on proportion of boxboard in the recovered paper mixture.*



8. Filtrate darkening depending on proportion of corrugated board or boxboard in the recovered paper mixture



9. Dirt speck area depending on proportion of corrugated board or boxboard in the recovered paper mixture.

portion of 12%, CB 5 causes an 11 point increase in filtrate darkening.

Figure 8 also shows that for all boards the filtrate darkening reaches nearly the same level at 3% board and 6% board. For the three boxboards this level is also reached at 12% in the recovered paper mixture. The corrugated boards show the steady increase in filtrate darkening with increasing proportion of board in the mixture.

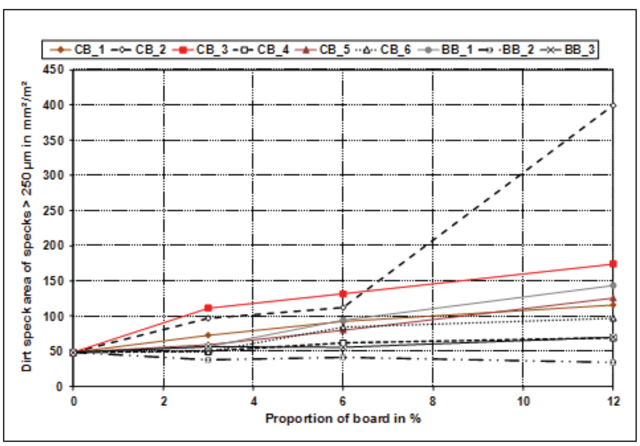
The dirt speck area is not significantly affected for nearly all investigated boards, as **Figs. 9** and **10** show. The total area stays the same in spite of the increase of the board proportion. The exception is CB 2, which had a high degree of printing and caused a flake content of about 1% in the deinked pulp when the proportion in the mixture was 12%. The flake content of most other boards was much lower.

The dirt speck area of specks with an equivalent circle area > 250 µm increases for all investigated boards, except for BB 2. For BB 2 the area of these large specks decreases with increasing board content. The increase in area for CB 1, CB 3, CB 4, CB 5, CB 6, BB 1, and BB 3 is approaching linear; CB 2 shows an increase of a higher order.

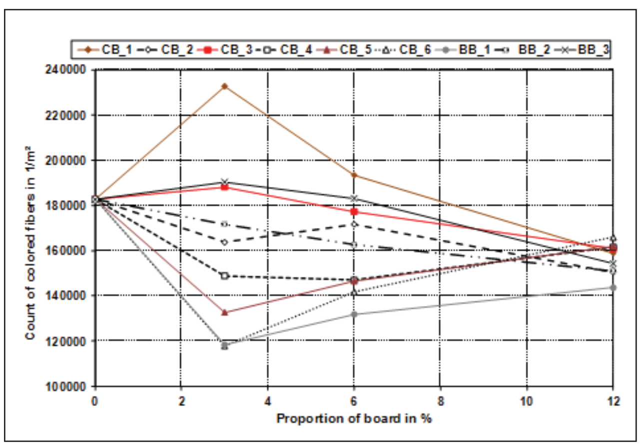
The count of colored fibers is plotted in **Fig. 11**. The results do not show a clear trend. Boards CB 1, CB 3, and BB 3 at a 3% proportion cause an increase in measured colored fibers and a decrease at higher proportions. For the other boards the image analysis system detects a lower count of colored fibers than for the board-free mixture. Because there is a color shift to red and yellow due to proportions of board in a recovered paper mixture, the colored fibers probably are not accurately detected by the image analysis system.

DEINKING RESULTS OF THE MIXTURES WITH DIGITAL PRINTS

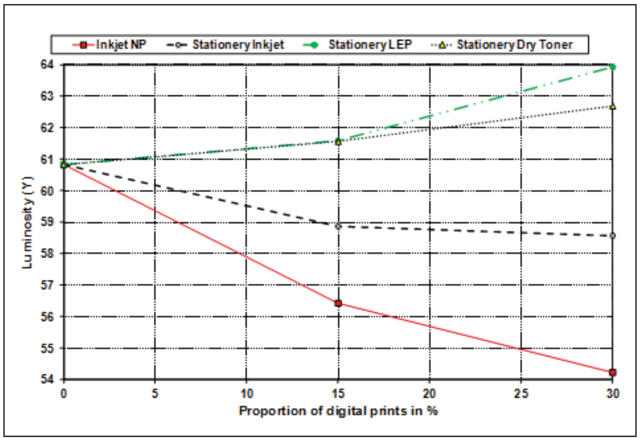
Digital prints in a recovered paper mixture behave differently depending on the print process. **Figure 12** shows the influence on luminosity. Whereas toner prints (LEP and dry toner) in a mixture lead to an increase in luminosity, inkjet prints (newspaper and stationery) cause a clear decrease. The largest decrease (7 points) is caused by inkjet printed newspapers. The increase in luminosity due to the toner prints (maximum 3 points) must be generated by the high luminosity of the base paper for the prints.



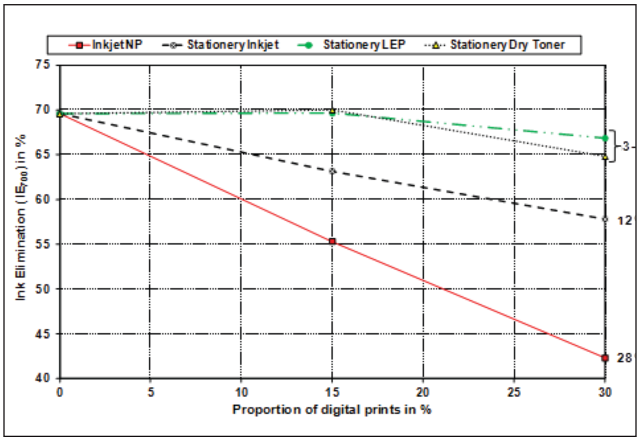
10. Dirt speck area of specks > 250 µm depending on proportion of corrugated board or boxboard in the recovered paper mixture.



11. Count of colored fibers depending on proportion of corrugated board or boxboard in the recovered paper mixture.



12. Change in luminosity depending on proportion of digital prints in the recovered paper mixture.



13. Ink elimination depending on proportion of digital prints in the recovered paper mixture.

The ink elimination (IE_{700}), shown in **Fig. 13**, is reduced by inkjet prints and toner prints. However, the ink elimination decreases (12–28 percentage points) due to the inkjet prints, whose printing inks are water based, and are much greater than those due to the toner prints (3–5 percentage points).

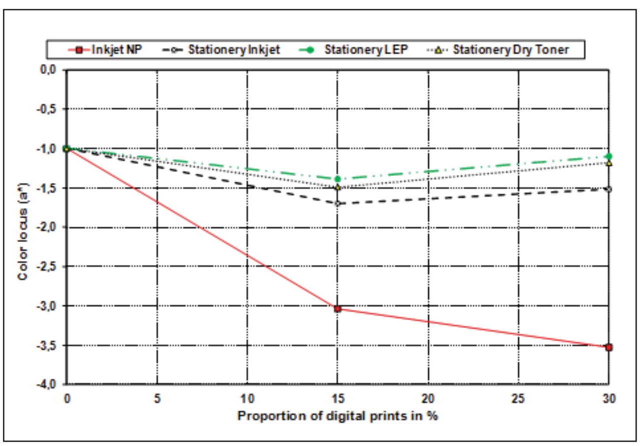
The color locus a* is strongly altered by the inkjet printed newspaper, as **Fig. 14** shows. The results show that proportions of inkjet printed newspapers in the recovered paper mixture shift the color locus of the deinked pulp to green. The other digital prints hardly impact the color locus of the deinked pulp. However, the inkjet printed stationery did not have the same printing degree as the inkjet printed newspaper. With the same degree of printing, the stationery inkjet prints should shift the color locus.

In **Fig. 15**, the filtrate darkening (ΔY) is plotted against the proportion of digital prints. The investigated dry toner prints reduce filtrate darkening in a mixture. For inkjet printed newspapers and LEP prints, as well as inkjet printed stationery up to a proportion of 30%, no strong effect on filtrate darkening was observed. But investigators [31] found that the filtrate darkening increases with increasing proportions of inkjet prints. Increasing proportions of inkjet textbook prints in a comparable recovered paper mixture led to an increase in filtrate darkening, but the filtrate darkening overall was not very high. A content of 30% inkjet textbook prints caused a filtrate darkening of 4.5 points [31]. The darkening results presented in this paper are on the same level.

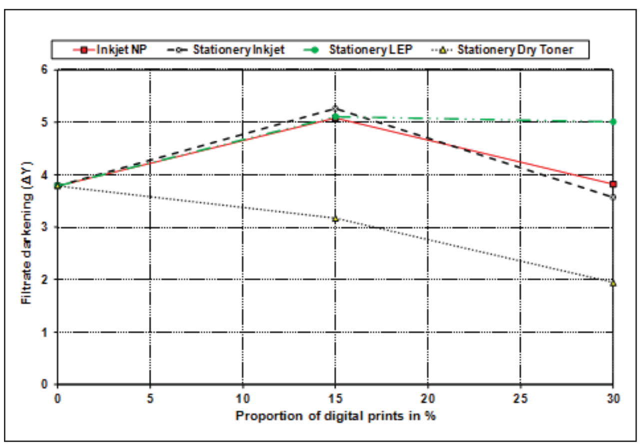
The dirt speck areas, displayed in **Figs. 16** and **17**, are mainly affected by LEP prints. With an increasing content of LEP in the recovered paper mixture, the area of small specks as well as large specks (> 250 µm) increases. For dry toner only, a slight increase in dirt speck area caused by small specks is visible. Inkjet printed newspapers in the mixture induce a reduction of dirt specks because water-based inks create no visible ink specks.

CONCLUSIONS

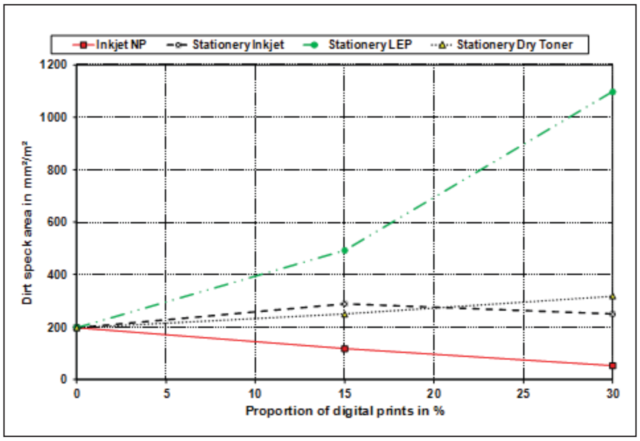
Proportions of boards and digital prints in a typical recovered paper mixture influence the optical properties of deinked pulp. Both brown and white-lined corrugated boards cause a decrease in luminosity and a shift in the color locus to red and yellow. Also, the filtrate darkening increases by the inclusion



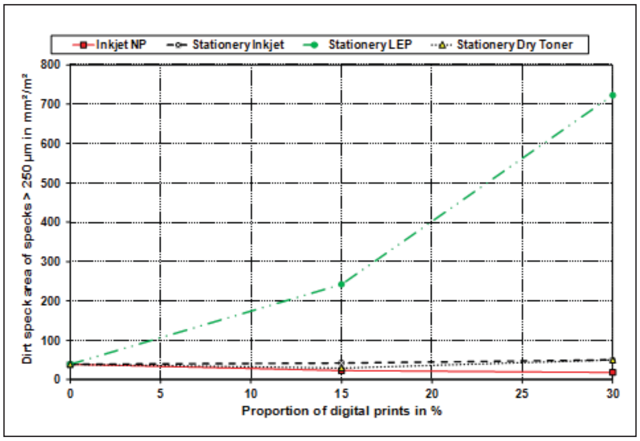
14. Change of color locus a depending on proportion of digital prints in the recovered paper mixture.*



15. Filtrate darkening depending on proportion of digital prints in the recovered paper mixture.



16. Dirt speck area depending on proportion of digital prints in the recovered paper mixture.



17. Dirt speck area of specks > 250 µm depending on proportion of digital prints in the recovered paper mixture.

of corrugated board. The total dirt speck area is not influenced by five of six corrugated board grades, but the area of large specks (> 250 µm) increased due to all corrugated boards.

Boxboard hardly influences luminosity. Only chipboard leads to a luminosity decrease of 2 points at a proportion of 12% in the mixture. Also, boxboard does not cause a color shift like corrugated board. Chipboard shows a clear shift to red and yellow. The filtrate darkening increased when boxboard is in the mixture but the darkening is at the same at board proportions of 3%, 6%, and 12%. The total dirt speck area does not change due to proportions of boxboard in a recovered paper mixture, but the content of large specks can increase.

Inkjet printed newspaper strongly reduces luminosity and ink elimination and induces a color shift to green. The filtrate darkening is not affected by inkjet printed newspaper. The dirt speck area decreases with increasing proportion of inkjet printed newspaper.

Stationery inkjet prints reduce luminosity whereas stationery toner prints increase luminosity. The increase due to toner prints can be explained with the high luminosity of the base paper. All three stationery prints reduce ink elimination, but the greatest decrease was due to stationery inkjet prints. The color locus is hardly affected by the stationery prints. The filtrate darkening is not affected by stationery inkjet or LEP prints, although dry toner prints cause a decrease in filtrate darkening. The dirt speck area is mainly influenced by LEP prints in a mixture. The area of small and large specks (>250 µm) rise with increasing content of LEP prints.

ACKNOWLEDGMENTS

The authors thank Bundesministerium für Wirtschaft und Technologie (BMWi) and Arbeitsgemeinschaft Industrieller Forschungsvereinigungen (AIF) for financing IGF project 17299N of the research association Kuratorium für Forschung und Technik der Zellstoff- und Papierindustrie. The project was financed by AIF in the context of the program supporting the cooperative industrial research (IGF) of BMWi as a result of a decision of the German parliament. **TJ**

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ABOUT THE AUTHORS


Hirsch


Voss


Putz


Schabel

We chose this topic to research because of our experience and knowledge of laboratory deinking of various print products, based on the use of tap water. We wanted to study the behavior of mixtures from different print products and the impact of difficult-to-deink print products and packaging material in the raw material mixture. This simulates the raw material mixtures treated in industrial processes.

The most difficult aspect of this research was selection of the material that might have an impact on deinking results. We addressed this by selecting representative samples from the market. The impact of the difficult-to-deink print products on the deinking results was expected. A surprising finding was the large variation of various packaging products on the deinking results.

The investigation makes clear which print and packaging products have the greatest negative impact on the deinking process. Mills can try to limit those products with the incoming recovered paper.

We will continue with further investigations and try to support laboratory results with pilot scale investigations.

Hirsch is application engineer at Freudenberg Filtration Technologies SE & Co. KG, Weinheim, Germany. Voss is manager, production technology, at Papierfabrik Utzenstorf AG, Utzenstorf, Switzerland. Putz is senior researcher and Schabel is department head, Chair of Paper Technology and Mechanical Process Engineering (PMV), Technische Universität Darmstadt, Darmstadt, Germany. Email Putz at putz@papier.tu-darmstadt.de.