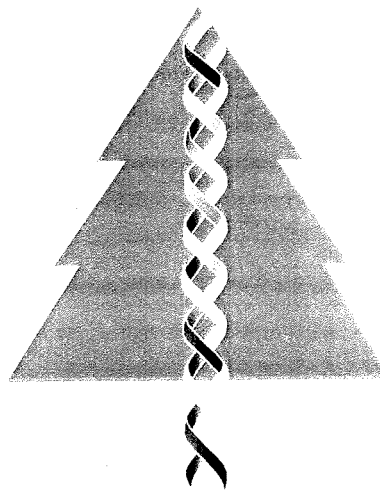


**ABSTRACTS**

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## LABORATORY DEINKING EXPERIMENTS USING MIXED OFFICE WASTEPAPER, PHOTOCOPY AND LASER PRINTS: CHEMICAL AND ENZYMATIC PROCEDURES

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### Introduction

Paper deinking, either chemical or enzymatic, is known to involve the study of a great number of factors, such that the maximum efficiency of the technique can be achieved. Process modifications are generally related to the type of furnish, namely fibre composition, additives and ink particle characteristics. Experimental routine is usually divided into five different operations: disintegration, pre-cleaning, chemical or enzyme treatment and flotation and/or washing. Each of them contributes differently to the overall process, depending on the sample that is being treated [1-7].

In the present work, it was our purpose to study and analyse the importance of each phase to achieve the optimal ink removal in different wastepaper samples.

### Methods and Materials

#### *Paper source*

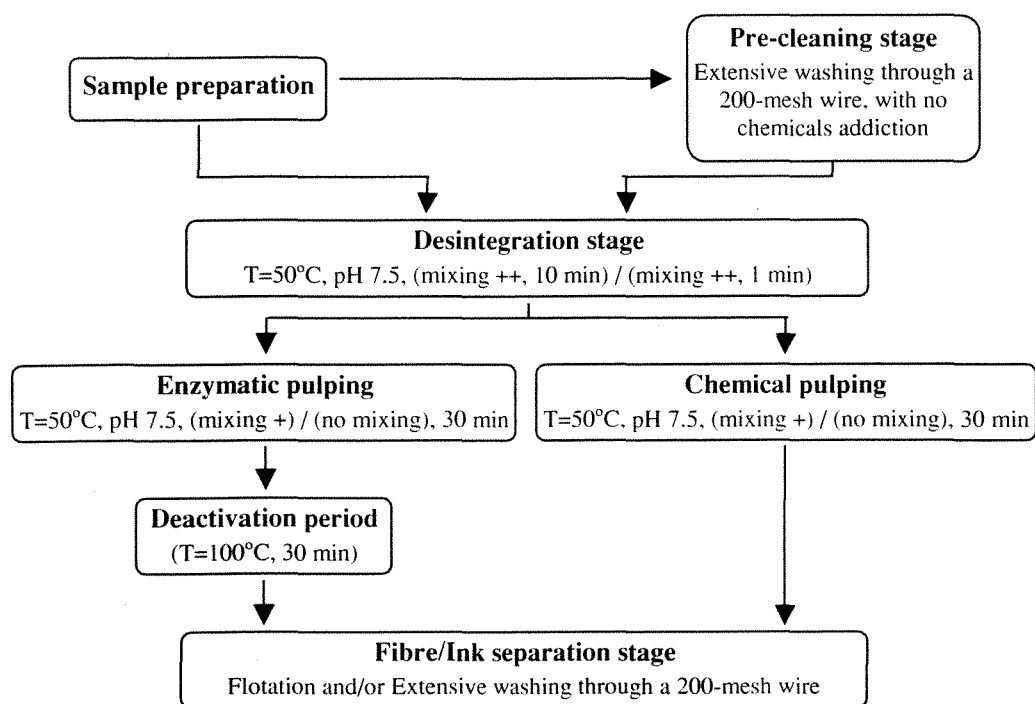
Several wastepaper samples were used to accomplish the purposes of the present work: (i) mixed office paper, *Renova* paper company; (ii) photocopy-printed paper (4% consistency, 1500 rpm, 50°C, 20 min); (iii) laser-printed paper (4% consistency, 1500 rpm, 50°C, 20 min); (iv) photocopy-printed paper (10% consistency, 750 rpm, 50°C, 20 min); (v) laser-printed paper (10% consistency, 750 rpm, 50°C, 20 min); (vi) photocopy/laser-printed paper (4% consistency, 1500 rpm, 25°C, 15 min).

#### *Deinking methodology*

The samples were treated according to the standard protocol presented in Figure 1 in order to test: (i) effect of the disintegration stage (different consistency batches); (ii) effect of a pre-cleaning stage before pulp treatment; (iii) effect of mixing during chemical or enzymatic treatment; (iv) effect of the fibre/ink separation stage (flotation or/and washing stages). Different enzymes and product dosages (either enzymes or chemicals) were tested in order to conclude about their effect in the pulp deinkability (Table 1).

#### *Deinking evaluation*

The process efficiency was evaluated by determining physical and mechanical properties of the pulp and paper (standard procedures) and by comparing the amount of ink present in paper sheets, before and after treatment, by using three different techniques: Image analysis, ERIC measurements and Brightness measurements.



**Figure 1:** Deinking experimental sequence

**Table 1:** Experimental conditions (Enzymes and Chemicals)

Enzymatic treatment (Filter paper and xylanase activities / g dry pulp)		Chemical treatment
<i>Xylanase Cd.</i>	--	103
<i>Celluclast 1.5L</i>	0.46	5.4
<i>Pentopan mono</i>	0.51	107
<i>AXC (Biocon)</i>	0.49	654
<i>Buzyme 2523</i>	0.12	1.3
<i>Novozym 342</i>	0.50	40
<i>IOGEN cellulase</i>	0.50	6.3
<i>SAFISYM CP.</i>	0.50	8.5

## Results and Discussion

### *Ink removal evaluation methodologies*

The accurate measurement of ink removal has been demonstrated to be difficult. Most of the published works report different methodologies to perform this evaluation and it is often hard to compare the obtained results. For that reason, we have decided to evaluate this parameter with different techniques: Image analysis, ERIC measurements and Brightness measurements. The obtained results revealed that the three techniques correlate only if the same sample is being considered and if the particle size distribution profile remains constant over the analysed sheets. As the relative amount of each particle size varies randomly depending on the applied deinking protocol, the ink removal efficiency is measured differently according to the method. Image analysis was selected as the more reliable one.

### *Effect of disintegration*

The disintegration methodology changes the pulp characteristics, specifically fibre strength and particle size distribution. Generally, increased pulp consistencies during this stage enhance burst, tensile and tear indexes and diminish the ink particles size. The major differences occurred in the laser-printed paper: 19% burst, 13% tensile, 2% tear and 27% particle size. The ink particles obtained during this initial stage will affect the deinking sequence, specially the fibre/ink separation methodologies.

### **Effect of a pre-cleaning stage**

The pre-cleaning stage was used before the enzymatic (*Buzyme 2523*) and chemical (2% NaOH, 2% NaSi) treatment of the mixed office paper sample. In both cases the deinked samples presented lower residual ink as compared with ones that were not previously cleaned. This effect was particularly important when the reactions occurred in the absence of mixing: a 26% decrease was detected after chemical treatment and a 30% decrease, after enzymatic treatment.

### **Effect of mixing**

The presence or absence of mixing was tested during the enzymatic (*Buzyme 2523*) and chemical (2% NaOH, 2% NaSi) treatment of a mixed office paper sample. According to the obtained results, mixing increases deinking efficiency when used simultaneously with the enzyme or the chemicals. The improvement is 8% for the chemical process and 16% for the enzymatic one. In either case the mechanical action seems to be complementary probably because it enhances product dispersion into the pulp and ink detachment from the fibres surface.

### **Effect of the fibre/ink separation stage: flotation or / and washing**

The tested samples presented different average particle sizes: mixed office paper (2359  $\mu\text{m}^2$ ) and 4%-photocopy/laser-printed paper (19265  $\mu\text{m}^2$ ). The different fibre/ink separation methodologies were applied after enzymatic (*Celluclast 1.5L*, *Buzyme 2523*) and chemical (2% NaOH, 2% NaSi) treatment of the samples. Both treatments had shown similar results. When chemicals or enzymes were used, extensively washing the mixed office paper pulp was sufficient to remove the dispersed ink. On the contrary, as the ink particles in the photocopy/laser-printed paper were larger, washing did not remove any of the present ink. In this case it was necessary to use a flotation device that could be followed by washing.

### **Effect of chemical treatment**

The chemical treatment efficiency was tested over the mixed office paper, the 10%-photocopy-printed paper and the 10%-laser-printed paper. Interesting efficiencies were obtained under the same tested conditions (2% NaOH, 2% NaSi): 31%, 37% and 18%, respectively. Additionally, all the strength indexes slightly increased after the treatment.

When other chemical dosages were applied to the mixed office sample different deinking efficiencies were obtained (data not shown).

### **Effect of enzymatic treatment: enzymatic preparations and enzyme dosage**

Several enzymes were tested over the mixed office paper, the 10%-photocopy-printed paper and the 10%-laser-printed paper (Table 2). The obtained results depend greatly on the enzyme/pulp combination. According to the enzyme dosages presented in Table 1, no enzymatic activity can be associated to the differential deinking performance, which indicates that an extensive study of characterisation should be considered on both the enzymatic activities and other components of the preparations. When other enzyme dosages (*Celluclast 1.5L*, *Buzyme 2523*) were applied to the mixed office paper sample, different deinking efficiencies were obtained (data not shown).

Generally, the enzymes action affected the paper strength. The worse results were obtained with *Buzyme 2523*, *Pentopan mono* and *SAFISYM CP.*, which damage the pulp to an extent that burst, tensile and tear decreased up to 14%, 10% and 34%, respectively. On the contrary, drainage increased by 14%. The best result was achieved with the *Celluclast 1.5L*, which was responsible for some strength improvement.

**Table 2:** Enzymatic deinking efficiencies (% residual ink)

	Mixed office paper	10%-photocopy-printed	10%-laser-printed
<i>Xylanase Cd.</i>	5	16	0
<i>Celluclast 1.5L</i>	18	0	0
<i>Pentopan mono</i>	20	12	0
<i>AXC (Biocon)</i>	35	22	0
<i>Buzyme 2523</i>	17		
<i>Novozym 342</i>	16	Not tested	
<i>IOGEN cellulase</i>	31		
<i>SAFISYM CP.</i>	12		

## Conclusions

Image analysis was selected as the more accurate technique to evaluate the residual ink in paper sheets and was used in all the performed assays.

Every stage of the deinking process is critical for the overall ink removal: (i) disintegration methodology changes the pulp characteristics (fibre strength and particle size distribution); (ii) the pre-cleaning stage seems essential to the process as it allows the removal of an increased amount of ink; (iii) mechanical action during enzymatic or chemical deinking seems to be complementary to the process; (iv) fibre/ink separation methodologies depend on the ink particles size.

Mixed office paper was the easiest furnish to deink and laser printed-paper was the hardest, either by enzymatic or chemical means. The efficiency of the enzymatic process depends either on the amount of chemicals or both enzyme type and dosage.

According to the present work, the enzymatic protocol can replace the chemical one, whenever mixed office paper is treated. On the contrary, photocopy and laser printed-paper are better deinked by using the chemical methodology.

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