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A Novel Eco-Alkali Chemistry in Newspaper Flotation Deinking

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Abstract:

This paper presents the study results of performance and efficiency of fresh offset-printed Croatian daily newspaper, deinked by means of novel chemistry, named Eco-alkali. Eco-alkali is naturally gained alkali prepared from domestic by-product wood fly ash collected after hardwood ignition. Brightness, opacity and effective residual ink concentration (ERIC) as optical properties were evaluated for the deinked pulp before and after flotation. Lingering ink particles and their total surface area were measured by means of image analysis method. Experimental results are compared to the pulp deinked with worldwide accepted method INGEDE Method 11, using identical steps through the whole deinking process. The insights obtained from present work, especially removing particle efficiency results before flotation, indicated that eco-alkali have potential to be used in flotation deinking of newspapers.

Keywords:

Eco-alkali, Newspaper, INGEDE Method 11, Flotation Deinking, Image Analysis, Optical Properties

1. Introduction

Waste paper has become an important source of fibres in pulp and paper industry throughout the world. The use of secondary fibres has considerably increased and deinking has become an important step in the recycling of fibre have significant role in ecological environmental approach. Recycling of paper waste can decrease municipal waste for ¼ (*Radman, A. et al. 2009*).

Re-cycling and sustainability are nowadays the main trends in paper recycling industries. Profitable conversion of this relatively abundant and inexpensive raw material into quality products requires efficient means of removing contaminants, inks being one problem. It is recognized that the flotation process is one of the most important sub-systems in a waste-paper recycling mill, as it provides a low cost and effective means of removing ink particles from recycled pulp *(Finch J.A. & Hardie C.A 1999)*. It represents the decisive process step as far as the improvement of optical characteristics of fibre stock, such as brightness and dirt specks, is concerned. Furthermore, flotation deinking is gaining importance in the separation of other contaminants, for example, stickies or fillers and pigments *(Kemper M. 1999; Vashisth S.et al. 2011)*.

A combination of chemical and mechanical forces is often necessary to remove ink particles from fibres. Mechanical force is usually supplied by a pulper, where paper is beaten into its constituent fibres. As mechanical force in the pulper is not sufficient for effective ink removal, surface active chemicals (e.g. NaOH, H_2O_2, chelating agent, etc.) are added in the pulper to decrease adhesion of the printing ink to the fibres and to increase ink removal efficiency. Conventional chemical deinking uses large quantities of chemicals, which require costly water treatment systems. In order to overcome these disadvantages and find an economical and environmental friendly combination of chemicals, many different chemical approaches during flotation deinking are applied by numerous researchers.

Application of soap and an alcohol combination instead of soap and peroxide in flotation stage can improve ink removal efficiency. The brightness of final pulp increases with the number of carbon atoms in alkyl chain (C1–C7) *(Behin J. & Vahed Sh. 2007)*. According to many experts, the use of enzymes is a possible and competitive strategy to deink recycled pulps *(Pala H. et al. 2004; Pe`lach M.A. et al. 2003; Zhang X. et al. 2008; Xu Q. et al. 2009)*, but enzyme selection and the optimization of the process are necessary in order to accomplish a good quality final product.

The use of cellulase-type enzymes may represent an alternative to conventional chemicals in repulping of old newspaper *(Pe`lach M.A. et al. 2003)*. According to *(Zhang X.et al. 2008)* cellulase deinking was less efficient than either alkaline or sulphite chemistry. Cellulase treatment alone was not effective for deinking aged old newsprint, but the combination of cellulase (Novozyme 476) and sulphite deinking chemistry showed promise to improve summer ink removal.

A synergistic deinking effect was observed between cellulase/hemicellulase and laccase-violuric acid systemLVS. The enzyme-combining deinked pulp gave higher brightness and physical properties, and lower ERIC than pulps deinked with each individual enzyme *(Xu Q et al. 2009)*.

While observing the use of cellulases/hemicellulases versus the laccase-mediator system for deinking printed fibres from newspapers and magazines, it became evident that both carbohydrate hydrolases deink the secondary fibres more efficiently in the way that enhanced optical properties of resulting deinked pulps from both newspaper and magazine secondary fibres, maintaining or slightly improving the strength properties. By contrast, the laccase-mediator system was ineffective at deinking both secondary fibres, resulting in deinked pulps with worse brightness and residual ink concentration values *(Ibarra D. et al.2012)*.

For offset prints, alkaline deinking appears the best solution *(Dumea N. et al. 2009)*.

INGEDE Method 11 (*International Association of the Deinking Industry 2009*) which uses alkaline conditions serves as a basis for comparing the deinkability of prints all over the word. According to this method, 81% of the offset prints – mainly newspapers and magazines – achieved a positive assessment of their deinkability *(Faul A. M. 2010)*.

All approaches commercially applied to date have not been successful in producing fibre qualities necessary for printing and writing grades and at the same time environmentally friendly. The idea of new naturally gained and easily prepared alkali chemical was born to use raw material and deinking chemicals of the same origin - wood. The aim of this research was to evaluate new type of alkali media used to remove ink from recycled newspaper via flotation deinking.

2. Experimental part

2.1 Materials

Fresh offset-printed daily Croatian newspaper was used as raw material (sample) for the flotation deinking investigations.

Chemistry used in deinking process, called Eco-alkali, is naturally gained alkali prepared as follows. Domestic by-product wood fly ash was collected after hardwood ignition. Hardwood (oak and beech tree) as the raw material for this new type alkali media was chosen because it is used in paper industry for obtaining virgin fibres as well. 500 g of collected ash was cooked in 4.0 L tap water until boiling. Suspension was cooled at room temperature, decanted and then filtrated by Büchner funnel with appropriate vacuum device using filter paper 589/3. The chemical composition of Eco-alkali was obtained by ion chromatography (IC) and inductively coupled plasma mass spectrometer (ICP-MS), Table 1.

2.2 Methods

Chemical deinking by flotation was done using three main apparatus: Enrico Toniolo disintegrator, laboratory flotation cell and Rapid Köthen Sheet Machine Automatic. Two deinking trials were carried out under the same experimental conditions, as can be seen in Table 2. The pulp for each deinking trial was produced from 80g oven-dry fresh offset-printed daily Croatian newspaper. In Trial 1 (T1) worldwide accepted method for flotation deinking, INGEDE Method 11 (*International Association of the Deinking Industry 2009*), was done as a control method for defining deinking efficiency of new alkali flotation deinking approach. Since the aim of this work was to minimize the environmental impact of chemicals for conventional flotation deinking, Trial 2 (T2) was done by applying only Eco-alkali without any additional chemical except surfactant, which is necessary for flotation. Chemical dosage applied in novel alkaline deinking, compared to the INGEDE Method 11, is presented in Table 2.

Table 1. Eco-alkali composition; pH=12.08, conductivity = 20.0 mS/cm

Anion (IC method), mg/L	Element (ICP-MS method), mg/L			
	concentration > 1,0 mg/L		concentration < 1,0 mg/L	
F- (3.78)	K (5781)	Mg (4.45)	Al (0.35)	As (0.01)
Cl- (27.2)	Na (162.6)	Fe (2.30)	Ag (0.10)	Mn (0.03)
NO3- (46.1)	Ca (10.65)	B (5.73)	Cu (0.105)	Zn (0.06)
SO42- (675.9)	P (7.1)		Pb (0.01)	

Table 2. Chemicals utilized in the novel alkaline method (dosage related to oven-dry paper)

Chemical	Dosage of chemical	
	Trial 1	Trial 2
	INGEDE Method 11	Our method
Alkali	0.6% sodium hydroxide	50mL Eco-alkali
Sodium silicate	1.8%	-
Hydrogen peroxide	0.7%	-
Surfactant	0.8% oleic acid	0.8% oleic acid

Handsheets, before and after flotation, were prepared from pulp gained from both deinking trials (Trial 1 and Trial 2) according to INGEDE Method 1 (*International Association of the Deinking Industry 2007*).

Particle size distribution and optical characteristics of handsheets before and after flotation were monitored using a Spec*Scan 2000 (Apogee Systems Inc.) and a Colour Touch 2 spectrophotometer (Technidyne Corporation), respectively.

Spec*Scan 2000 (Apogee Systems Inc.):

- Total particle number
- Total particle area
- Particle size distribution

Colour Touch 2 spectrophotometer (Technidyne Corporation):

- Opacity
- ERIC
- ISO brightness

2.3 Measurements

Spectrophotometric and image analysis results are presented as average value of five measurements on upper and bottom side for the same handsheet sample, prepared from fresh offset-printed daily Croatian newspaper pulp before and after flotation.

Image analysis was performed in reflection mode on the 64.000 mm^2 handsheet surface, in particle size range from 0.001 to 5 mm^2 and higher, divided into 25 size classes. From image analysis measurements total particle number and total particle area for each size class were obtained. These measurements have to be in accordance with optical characteristics (brightness, opacity and ERIC) of the sample.

By TAPPI T 452 standard, brightness is defined by reflection value of the observed sample on the wavelength of 457 nm, at which the reflected light is measured which passes through the blue filter. The brightness (R_{457}) method was developed to monitor the bleaching of pulp, because at these short wavelengths (from 400 to 500 nm), reflectivity is changed the most *(Pauler N. 2001)*.

The measurement of effective residual ink concentration (ERIC) in recycled papers depends on their opacity. Opacity is a fundamental optical property of paper and is determined by a ratio of reflectance measurements. The opacity of the sheet is influenced by thickness, the amount and kind of filler, degree of bleaching of the fibres, and coating. The spectrophotometer used in this research (Colour Touch 2) applied printing opacity algorithm as the ratio of the reflectance of a sample when backed with a black body to the reflectance of the sample when backed by multiple sheets of paper (R_0/R_∞).

By converting the infrared reflectance measurements of paper to a coefficient for light absorption, ERIC technology provides a control parameter specifically to measure the residual ink content. From those measurements, ERIC provides data for determining how much deinking and/or bleaching is necessary to achieve target brightness.

3. Results and discussion

The handsheets obtained with standard chemical deinking, INGEDE Method 11, have been compared to those obtained with Eco-alkali method, using identical steps through the whole deinking process. Lab scale flotation deinking efficiency was controlled through handsheet optical characteristics evaluation and particle distribution. All image analysis (Figure 1., 2., 3.) and spectrofotometric handsheets measurements (Table 3.) were done for each trial handsheets formed before and after flotation and presented as average value of five sequentially measurements.

From image analysis results we can conclude that chemistry used in T1 (INGEDE Method 11) has shown better particle removing from disintegrated pulp for particle size range from 0.013

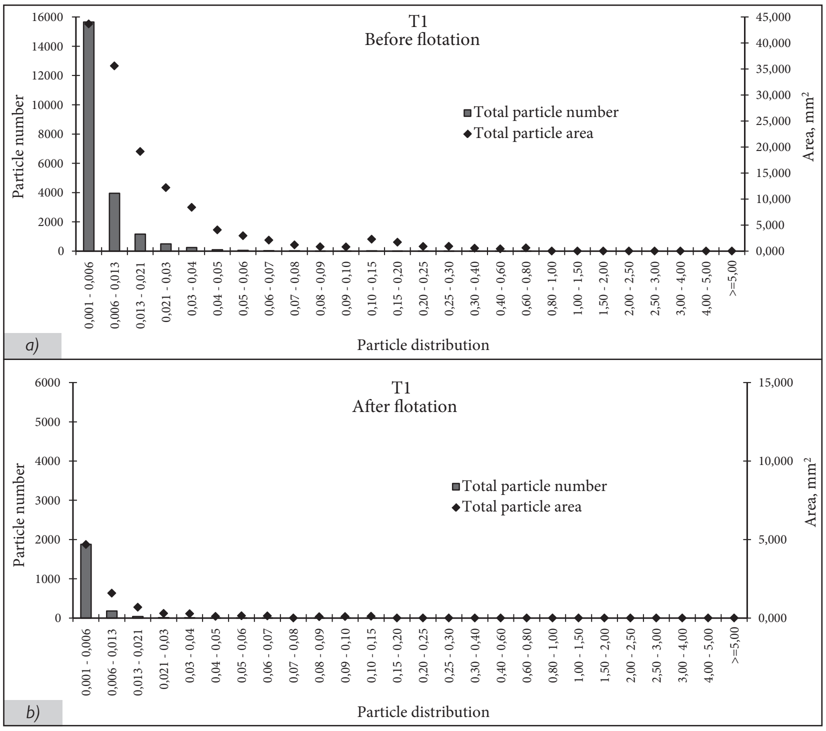

Figure 1. The image analysis results for handsheets formed by Trial 1 before (a) and after (b) flotation (particle size, mm2 and total particle area, mm2)

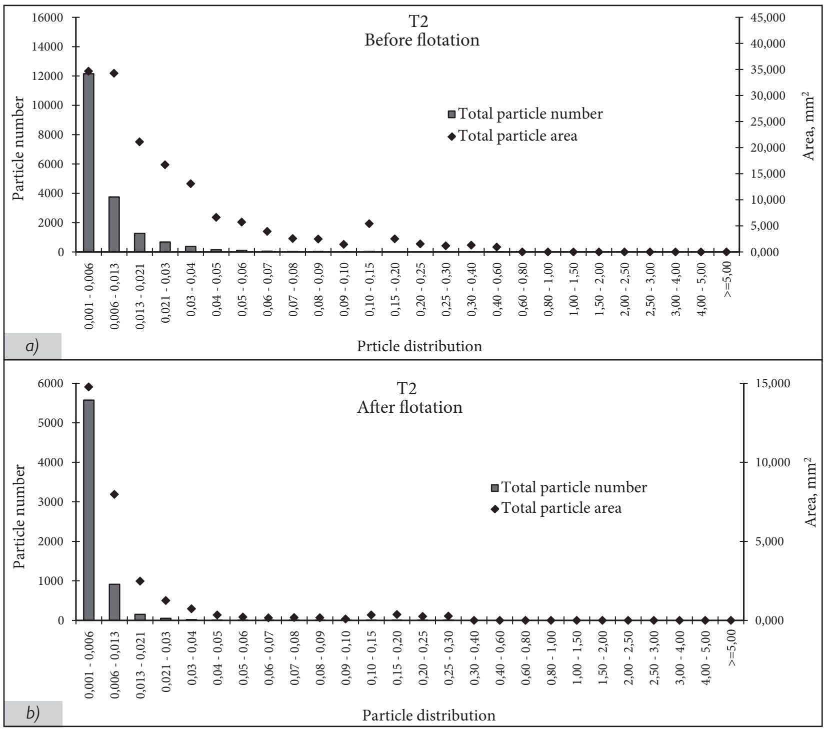

Figure 2. Image analysis results for the handsheets formed by Trial 2 before (a) and after (b) flotation (particle size, mm^2 and total particle area, mm^2)

to 0,30 mm² (Figure 1.a), while Eco-alkali used in T2 has shown better efficiency in removing the smallest particles from 0.001 to 0,013 mm² (Figure 2.a). Particle removal efficiency by flotation process is significantly higher for T1 method especially for the smallest particles 0.001 to 0,006 mm² (88%) in comparison to T2 method (54%). For higher particle size range, 0.006 to 0,013 mm², that difference in particle removing efficiency is slightly smaller (T1 – 95%, T2 – 76%), and for each further size range that difference is practically indiscernible.

Both methods (T1 and T2) show 100 % efficiency removing for higher size particles, before flotation from 0,60 to 5,0 mm² and after flotation from 0,30 to ≥ 5,0 mm².

Figure 3 demonstrates comparison of particle distribution for T1 and T2 for the three smallest particle size ranges (0,001-0,006; 0,006-0,013; 0,013-0,021), as the flotation deinking efficiency for these two methods has shown significant differences in particle number values.

Optical handsheets characteristics confirm the image analysis results. Optical control parameters ERIC and brightness show better deinked efficiency achieve by T1. After flotation brightness value is improved by 15% while in T2 only by 6% (Table 3.) and ERIC values are improved by 43% and 32%, respectively.

During the process of disintegration we get better particle removing efficiency with Eco-alkali than with INGEDE chemistry, especially for the smallest particle size class (Figure 3.). As we can see from our image analysis results, flotation process with Eco-alkali, when we compare it with INGEDE chemistry, shows lower particle removing efficiency. During flotation process we used INGEDE method 11 conditions for both trials (T1 and T2) which have optimal values for trail T1. As we change main chemistry used in T1, we have to change parameters for flotation process as well. Flotation process depends on the type used, as well as on surfactant concentration, flotation duration and temperature, so we have to adjust these parameters in order to obtain better flotation particle removing efficacy.

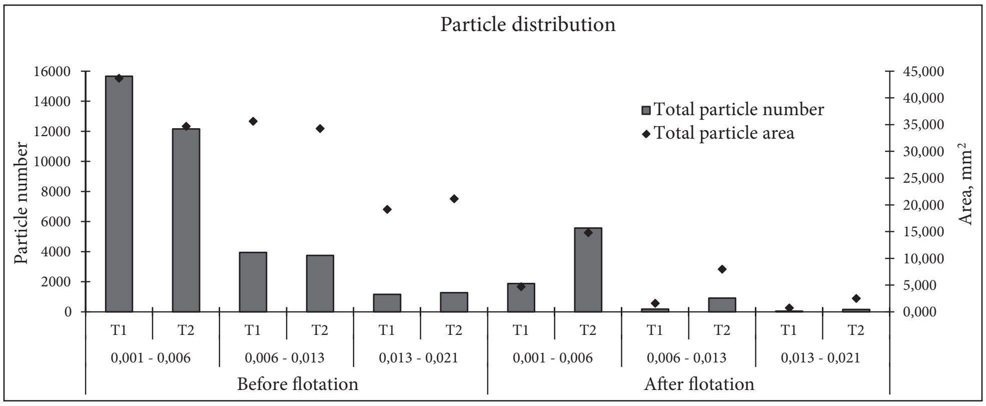

Figure 3. Particle distribution comparison for Trial 1 and Trial 2 for the three smallest particle size ranges (particle size, mm² and total particle area, mm²)

Table 3. Handsheet optical data

Trial	Flotation	Opacity, %	ERIC, ppm	$\frac{ERIC_{BF} - ERIC_{AF}}{ERIC_{BF}} \times 100$	ISO Brightness,%	$\frac{R_{460\,BF} - R_{460\,AF}}{R_{460\,BF}} \times 100$
T1	BF	95.01	636,3	43%	46,34	15%
	AF	97.19	361,3		53,43	
T2	BF	98.28	892,2	32%	46,07	6%
	AF	97.99	603,9		49,11	

4. Conclusion

The aim of this study was to evaluate practical usage of laboratory prepared novel alkali chemistry (Eco-alkali) in newspaper flotation deinking trials. The primary criteria for flotation deinking chemistry performance are the brightness of the deinked pulp and the number of visible ink specks per unit surface area of paper made from the deinked pulp.

Image analysis and spectrophotometric measurements results for handsheets formed before flotation with Eco-alkali and compared to results for handsheets formed before flotation with commercial flotation deinking chemistry, implies that Eco-alkali in newspaper recycling process are successfully used. According to the results presented, there is a need for further detail investigations so as to achieve optimal process conditions (especially surfactant type and concentration, disintegration duration and temperature) for improving flotation deinking efficiency of Eco-alkali.

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