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Comparison Of Conventional And Recycled "Green" Office Paper

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Abstract
To confront with the market need, we have to find alternative in respond to enormous necessity and application of office paper. Therefore, one way in dealing with the problem is to replace or just decrease the use of paper made entirely from primary components, mainly wood fibbers (deciduous and conifer). We analysed mechanical, optical, structural and microscopic properties. Experiments were performed on three conventional and three recycled office papers reachable on the market. Results, obtained from measurements, confirm presumption, that mechanical and surface properties of recycled office paper can be collated and they discern from conventional office paper.

Key words: conventional, recycled, office papers, mechanical, optical, surface, microscopic properties.

1. INTRODUCTION

The success of waste paper recycling is highly dependent on securing a satisfactory level of public participation (Ball and Tavitian, 1992). Countries measure effectiveness of their waste reduction programs mainly upon two general approaches. First, on the basis of recycling rates and second, on the disposal reduction rates (Wenger et al., 1997) and (Nakamura, 1999). If waste paper is incinerated instead of reused, energy purchases from society will consequently be reduced and that will have a positive effect on a CO_2 emissions. However, pulp and paper mill discern in its ability to either use recovered waste paper as a primary fibre source or as energy for its self or society (Byström and Lönnstedtl, 2000). Paper recycling has in Europe long tradition. Manufacturing paper from waste has developed into an extensive organization. In 2004 was in Europe accumulated 55% or. 46,2 million tons of waste paper. (International Institute for Enviroment and Development, 2002 and 2004). Half of it represents preconsumer segment, such as unsold periodicals, magazines, newspapers, reviews and other publications (Možina, 2006). According to IIED, more than 95% of information is still stored on paper (International Institute for Enviroment and Development, 2002 and 2004). Most commonly we link paper usage with reading, writing and printing. Nowadays modern communication technologies are preliminary oriented in packaging. Packaging represents largest single segment of paper consumption that is 41% (Anon, 2003). After all, one uses 115 billions sheets of paper, while average Internet user prints 28 sheets of paper per day (Hewlett Packard, 2005). However, promotion of sustainable consumption and production patterns is enshrined as a key objective in the renewed European Union Sustainable Develop-

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ment Strategy (EU SDS). Sustainable consumption and production is in the most challenging aspect of the EU SDS and it requires changes to the way products and services are designed, produced, used and in the end, disposed of (Nash, 2009). Mentioned above has led us to investigation possibilities to replace conventional office paper with recycled. Research presented in this work has not have just scientific whiff, where all the arguments for using recycled office paper are quantitatively evaluated, but it also has practical meaning, and that is, to stimulate users towards more economical handling, along with not such significant abjuration.

2. EXPERIMENTS

2.1. Problem statement

In recent years many counties, not to mention, especially developed one, have established and promoted paper recycling. Although countries share the same basic recycling structure system, they all have some unique features and ways of dealing with the problem (Kishino et al., 1999). Recycling is grounded on collecting and reusing materials, such as, paper, plastic, glass, aluminium and textile. But all waste materials are not renewable. With recycling process we established system in which offal becomes source for production of something new (Možina, 2007). On the other hand, difficulty of collecting and sorting waste paper, the low process yield and the energy required or reform the used paper, makes recycling process economically unattractive and potentially environmentally less preferable, than paper produced from primary fibres. The main goal of office paper recycling is to remove added print on the paper surface (Counsell and Allwood, 2006). The conventional recycling process can be divided into four steps: collection, print removal, reforming and delivery. Print removal is unique to paper recycling and will be considered in detail here. Collection process is similar to that of other recycled products, while reforming and delivery are identical to those used in the production of paper from primary fibres. The need for two sorting steps makes the collection of waste paper to be recycled more entangled than the collection of blended office offal's. The end user, with placing used office paper into a separate waste bin, often does the first sorting steps. At this point, paper recycling includes removal of ink (deinking), paper coating, glue, paper clips, package covers and cords. Because collected waste is a mixture of diversified range of paper types, from newsprints, magazines, brochures, packaging materials and office paper, a range of separation technologies must be used. Thompson proposed usage of filters for particles greater than 0,2 mm, which is rear for modern print, but convenient to remove other contaminates; centrifugal cleaners for particles in range between 0,1 and 0,4 mm, which may contain some toner and large pigment prints and it is also aimed at other contaminants; flotation for particles size 0,05-0,15 mm (most toner print); washing for water soluble inks and those with particles below 50 µm (ink-jet and industrial print). Size of print particles can be reduced either by dispersion or increased by agglomeration (Counsell and Allwood, 2006) and (Thompson, 1998).

Deinking is important for paper recycling and usually flotation is used for deinking. In the case of office wastepaper, photocopy and laser print toner particles are thermally fused and bonded to cellulose fibres that make deinking some more difficult than common waste paper (Hue et al., 2000). Deinking is a term describing a process for detaching and elimination of unwanted additives, such as printing inks from recycled papers to improve optical properties of pulp and consecutively, of end recycled paper (Behin and Vahed, 2007) and (Tyler, 2000). Deinking is also brightening of gained fibres, or so called ”fibre washing”. Chemical factors are critical in impurity removal. They influence the efficiency of removal of undesirable additives and final brightness. Overall flotation deinking can be divided into four basic micro processes (Bloom and Heindel, 1997):

1. collision or capture of an ink particle by air bubble;
2. adhesion of an ink particle to the air bubble by sliding;
3. development of a three phase contact at the air bubble-water-particle interface;
4. bubble-particle stability or instability after an aggregate is formed.

Important parameter is also pH value, which in alkaline media influences swelling of cellulose fibre and accelerates glue and ink removal. Increased pH value affects hydrolysis of ink binding agent, which, in further, influences on detachment of printing ink from cellulose fibre surface and on the size of dispersed printing ink particles. Use of surfactants improves effect on elimination of impurities. Size of impurities depends on surface activity substance and thermo-mechanical forces at process of bonding toner on the printing substrate. Surface activity substances have in flotation process mayor impact on surface chemistry of particles and on air bubble formation. The mechanism of ink removal from cellulose fibre surface contains dissolving surface activated substances in water, increasing wetting of cellulose fibre by surface active substances and cellulose fiber swelling, that influences on reduction of adhesion of printing ink on the fiber surface and decreases intermolecular linkage. Ink and printing ink differ in structure and surface chemistry. They act differently in deinking process, at mechanical blending, added chemicals, washing, flotation, etc. Size of dispersed particles influences on sorting efficiency, cleaning, washing and flotation, and as consequence of mentioned, on papers optical properties. Pulp cleaned and prepared in such way is included in paper production just as minor part or in full 100%, from which manufactured paper is pure recycled paper (Tyler, 2000).

In recycling process, normally fibres are damaged, mostly because of drying actions in previous stages of paper production; so primarily fibres become shorter and fibre morphology is deteriorate. If we wish to maintain paper structure, it is necessary in most cases of recycled paper, to add primary cellulose fibres. (Novak, 1998). Reuse of waste paper is not exclusively green oriented. Production of 1 ton of ”new” paper demands approximately 1,4 ton of waste paper or 60 m^3 of fresh water, that has to be for deinking purposes heated and chemical additives are needed. On the end of recycling process, outflow contains, beside chemicals, also printing inks, which represents solid waste that has to be removed (Možina, 2004). Positive side of recycling is nature conservation, mainly from decreased necessity for land-field used in solving waste problem.

2.2 Materials and methods

In research were included two commercial papers (conventional and recycled) with three different type of grammage (100, 150 or. 160 in 200 g/m^2). Conventional office papers are labelled from 1–3, while recycled are marked from 4 to 6. Investigated conventional papers are product of Fabriano, with commercial name Multipaper and recycled office papers, named Nautilus, were manufactured by Mondi, Austria. Selected papers are general representatives of each investigated groups of paper, with which the quality difference and end use are estimated and mostly, they give an answer, if recycled office paper can replace conventional?
Used methods were selected upon papers usability, i.e. it end-use. Therefore research was divided into six categories to describe the material, e.g. elementary, mechanical, optical, surface, structural and microscopic characteristics.

3 RESULTS AND DISCUSSION

Research was divided into six sections: elementary, mechanical, optical, surface, structural and microscopic properties determination.

3.1 Elementary properties

For better understanding and comparison subsequent results, it is first necessary to present elementary characteristic of studied papers, such as are: grammage (ISO 536) (Fig. 1), density (ISO 534) (Fig. 2), moisture content (ISO 287) (Fig. 3) and determination of residue (ISO 1762) (Fig. 4). As it can be seen from Figure 2, recycled office paper has (in average) 6,7% higher density as conventional and in case of moisture content (Fig. 3) and 37,5% lower moisture content as conventional. Moisture binds with cellulose fibres. Higher moisture content indirectly influences on a higher fibre content. As conventional paper has in comparison with recycled one, better optical properties, manufacturer adds paper filler, in average 20%, to improve imperfection, such as brightness and opacity (Fig. 4).

3.2 Mechanical properties

With mechanical properties, paper resistance to outer influence is defined. Studied and presented mechanical properties are: tearing resistance (ISO 1974) (Fig. 5), bursting strength (ISO 2758) (Fig. 6), tensile strength (Fig. 7), and elongation at break (Fig. 8) and breaking length (ISO 1924/2) (Fig. 9). Alleged parameters significantly influence the end use. They give enough representative arguments in favour of application recycling office papers, as well as in offices, as in home

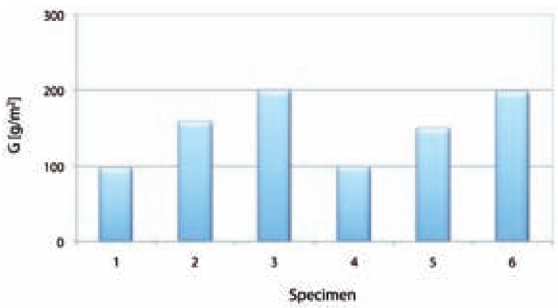

Figure 1. Grammage.

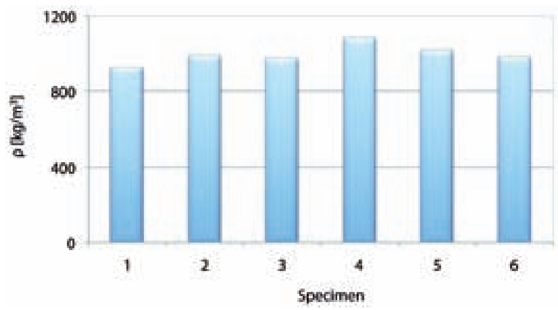

Figure 2. Density.

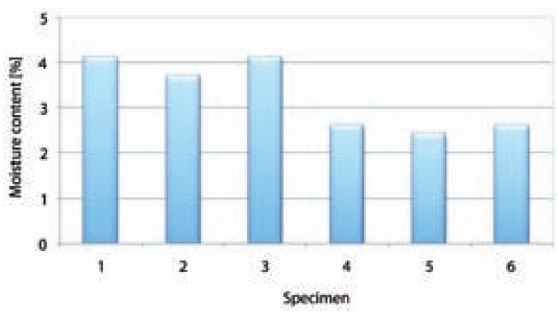

Figure 3. Moisture content.

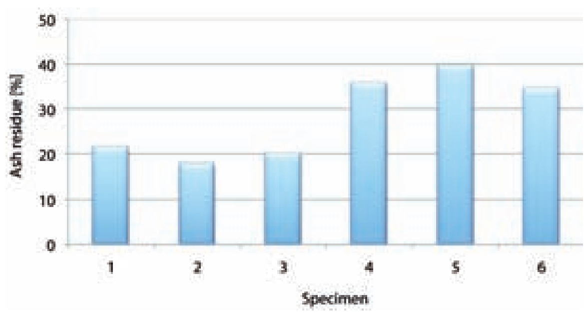

Figure 4. Residue (ash).

usage. Especially, where there are no demands for sustainability of printed documents over 10 years. There are more than 90% of all printed documents that can be classified as those above mentioned.

Tearing resistance was measured on Elmendorf. Results obtained from Elmendorf are presented in Figure 5, from which it can be seen, that there are no mayor differences between two studied papers.For instance, tearing resistance in specimen 1 in MD is 2,8 N, while is in specimen 4 the aexactly the same, i.e. 2,8 N. The similar trend can be seen in all further studied papers, except between specimens 2 (5,0 N) and 5 (2,9 N) in MD.

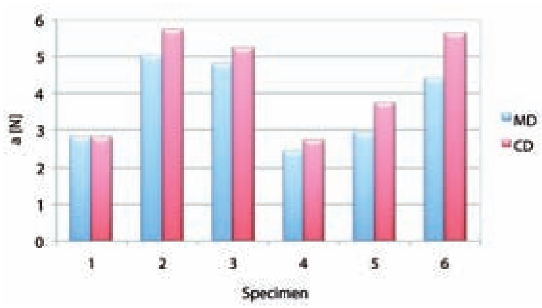

Figure 5. Tearing resistance.

Results of bursting strength carried out with Mullen method are presented in Figure 6 and they can be compared with results of moisture content (Fig. 3). Bursting strength of conventional office paper is 25,9% (e.g. S1 (190 kPa) vs. S4 (141 kPa) in MD) higher in comparison with recycled. Main reason for such difference is in paper filler content or is in relation fibre/paper filler, as it is described in chapter of elementary properties. Higher the filler content, lover the connection between the fibres will be, as well as less force to tear or pressure to burst paper is needed.

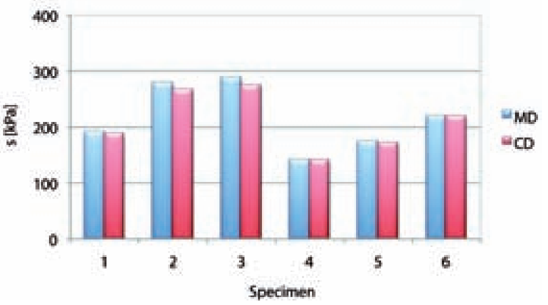

Figure 6. Bursting strength.

Measurements of tensile strength (Fig. 7) and elongation at break (Fig. 8) were conducted on dynamometer Instron 5567. Results are in close relation with bursting strength. Tensile strength for specimens 1–3 (conventional office paper) in comparison with specimens 4–6 (recycled office paper) are in machine direction (MD) 20,3%(e.g. S1–3; 74, 119 and 141 N, while in S4–6; 69, 87 and 110 N) and in cross direction (CD) for 38,8% higher (e.g. S1–3; 48, 69 and 77 N, while in S4–6; 28, 36 and 55 N). Similar distinctions among specimens 1–3 and 4–6 are noticed from the results of breaking length (Fig. 9).

Mechanical properties of recycled office papers are somewhat diminished and are consequence of application higher quantity of paper filler. Paper filler influences mechanical properties of paper, because they decrease number of linking between cellulose fibres. On the other hand, paper fillers have positive effect on optical properties as it is presented further.

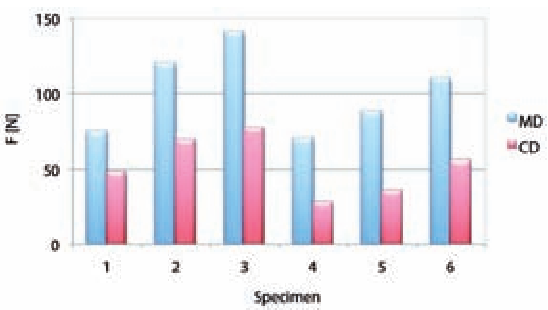

Figure 7. Tensile strain.

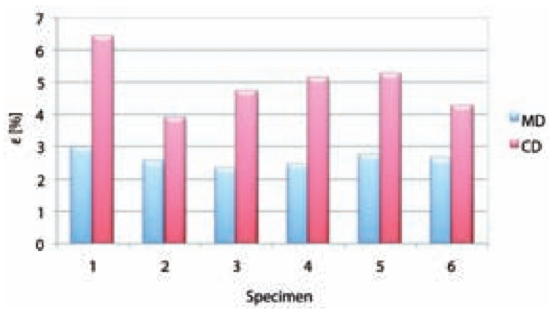

Figure 8. Elongation at break.

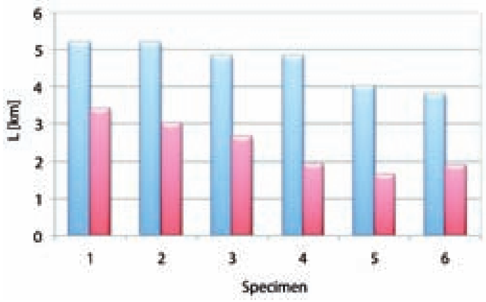

Figure 9. Breaking length.

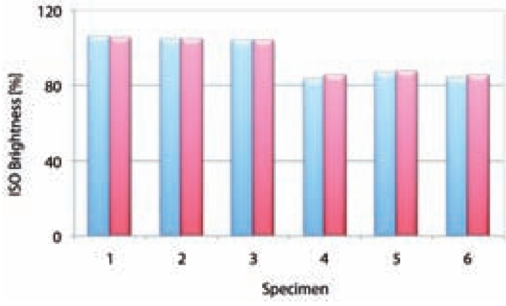

Figure 10. ISO brightness.

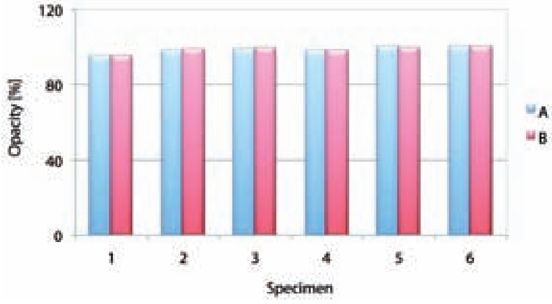

Figure 11. Opacity.

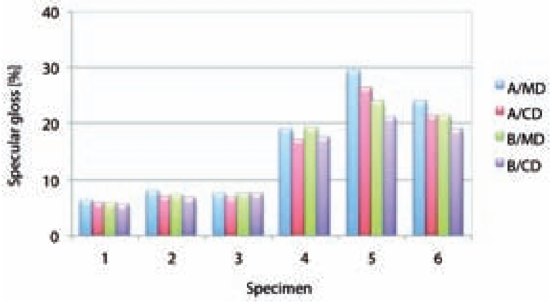

Figure 12. Specular gloss.

3.3 Optical properties

If comparing measured values of ISO brightness (ISO 2470) (Fig. 10) of both studied papers, one can see the difference between studied papers, but they should be considered with some reserve. Both office papers exceed over 85% value of ISO brightness, which is for usual use, such as reports, notes, conclusions, notification and notebooks, utterly sufficient level. Specimens from 1–3 have 10% higher value of ISO brightness (around 105%) in comparison with specimens 4–6, which do have ISO brightness around 85% and what is good relation to the expectation of brightness of recycled papers. On the other hand, opacity (ISO 2471) (Fig. 11) does not expose any mayor difference among specimens and between paper sides (A and B). From Figure 12 and from pictures of paper surface, taken with optical microscope (Fig. 26–31), are noticed higher values of specular gloss (TAPPI T480 om-5) for recycled papers, which are near 20%. Higher paper filler content is the leading cause for such measured values, where recycled paper has 10% more filler than conventional.

3.4 Surface properties

Measurements of paper roughness were carried out according to Bendtsen method (ISO 5636-3) (Fig. 13). Results confirm mentioned fact of possibility to exchange conventional office paper with recycled, because between studied papers there are no major distinctions in roughness, except in case of specimen 6, that resigns from other specimens for 56% (60–120 ml/min for conventional and 50–200 ml/min for recycled papers). Roughness significantly influences print quality, while air permeability (Fig. 14) has impact on possibility of a both side printing. From Figure 14 it can be seen, that recycled office paper has no detectable air permanence, in fact the measured value is 32 times (290 vs. 9 ml/min) lower than at the conventional office paper. Structure of recycled paper is denser, closed up and rigid, but imprints made on recycled papers have higher optical density and have lover printing ink penetration depth. Although recycled office paper is not as bright as conventional office paper (Fig. 10), the end impression or information printed on it, are somewhat equivalent.

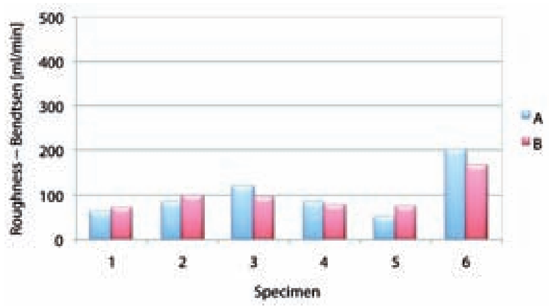

Figure 13. Roughness.

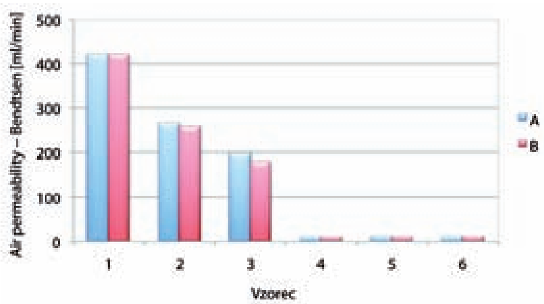

Figure 14. Air permeability.

3.5 Structural properties

Structural properties of office papers were determined with capillary rise - Klemm method (ISO 8787). Method was chosen upon practical application of studied papers. Office papers primarily become in counter with a dry printing technique (laser printers and photocopier) and partly with a wet technique, such as inkjet printing. Latest technique is mainly used for printing documents in full colour, while first two (laser printers and photocopier) are still predominantly used only for black/white documents, because toner expense for colour laser printers or photocopier still represents significant financial extent to company. Results obtained from determination of capillary rise, presented in Figure 15, clearly indicate reciprocity with values of air permeability (Fig. 14). Higher the air permeability, lower the capillary rise. High air permeability is a consequence of greater distance between fibres, less chain linkage between fibres are present, lower the capillary rise will be.

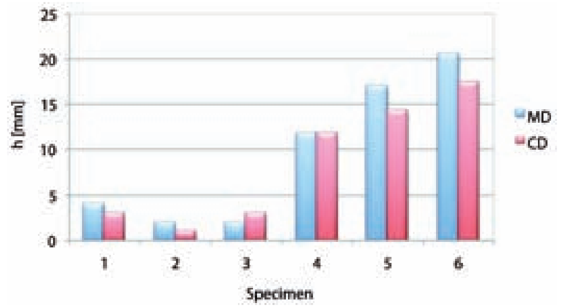

Figure 15. Capillary rise.

Conventional office paper; **Optical Microscope Olympus CX21**

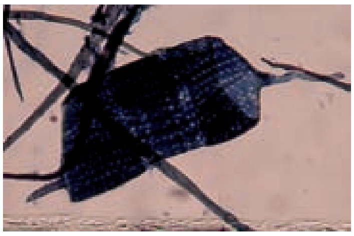

Figure 16. Eucalyptus.

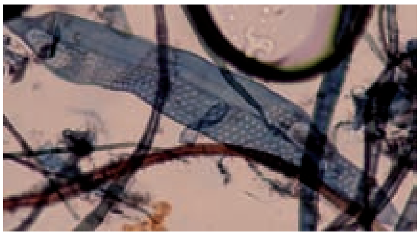

Figure 17. Poplar, spruce.

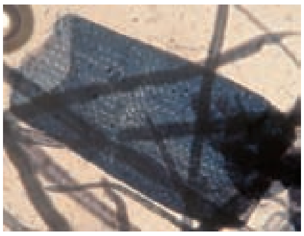

Figure 18. Beech.

Recycled office paper; **Optical microscope Olympus CX21**

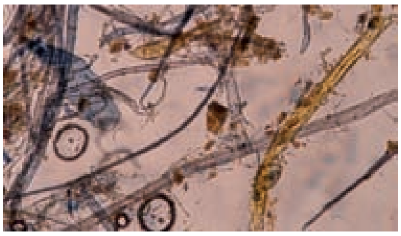

Figure 19. Poplar, spruce.

Figure 20. Poplar.

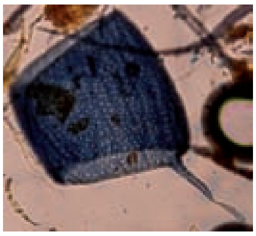

Figure 21. Eucalyptus.

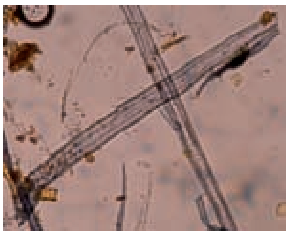

Figure 22. Pine.

Figure 23. Birch.

Figure 24. Beech.

Figure 25. Mechanical pulp.

3.6 Microscopic properties

Pictures of fibres in Figure 16-25 were taken with optical microscope Olympus CX21, at magnification 100 or 400, while pictures of studied office papers surface are presented in Figure 26-31, and were taken with optical microscope Leica EZ4D, at magnification 35. In Figures 16-18 are presented fibres from conventional office paper and in Figures 19-25 are pictures of fibres that are incorporated in recycled office paper. In both papers are found coniferous fibres, spruce and pine, and deciduous fibres, such as eucalyptus, poplar, beech and birch. In recycled papers are understandably found larger variety of cellulose fibres, where can be found beside primary cellulose fibres also mechanical pulp. Reason for that is, because the origin of fibre has no significant meaning, as the texture of end use does. Also, it is easier to control primary inputs, such as fresh cellulose fibres, where manufacturer prescribes what kind and in what portion will cellulose fibres be found in produced paper. Recycled paper consists fibres that are evidently shorter and more damaged. Mentioned is a consequence of a several passage through technological process of pulp preparation. Paper produced from such prepared fibres (recycled) has worse mechanical properties, because probability for chemical as well as mechanical interaction between fibres is lower, mostly because of the fibre surface hornification and stiffness of the individual fibres, as it is in case of primary cellulose fibres added in the pulp for the first time.
Figures 26-31 shows equality of studied paper surface and consequently on possibility to change or partly replace conventional office paper with recycled. Analogy can be seen from measurements of Bendtsen roughness, presented in Figure 13.

4 CONCLUSIONS

Paper recycling and its reuse, decreases need for acquisition cellulose fibre only from wood. Cellulose and paper making industry belong among those branches that are major consumer of natural and renewable raw materials. Mainly those are wood, energy (e.g. fossil fuels, hydro and nuclear power plant) and especially water resources. Characteristically for cellulose and paper making industry is, that during manufacturing, equal quantity of wastewater is produced as fresh water is brought into the process. And at the same time, mentioned production known for loaning water from nature and returning it more purified, as it was taken into the production process. Collecting waste paper has positive affect on economical indicators, as cost

Optical Microscope Leica EZ4D

Conventional office paper

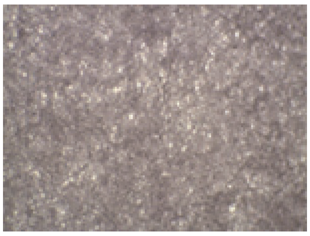

Figure 26. Specimen 1 (100 g/m^2).

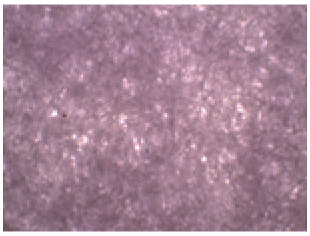

Figure 27. Specimen 2 (160 g/m^2).

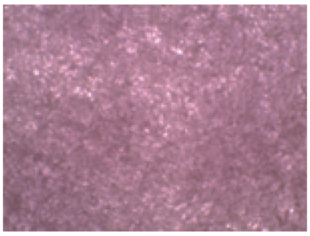

Figure 28. Specimen 3 (200 g/m^2).

Recycled office paper.

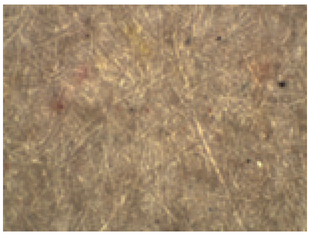

Figure 29. Specimen 4 (100 g/m^2).

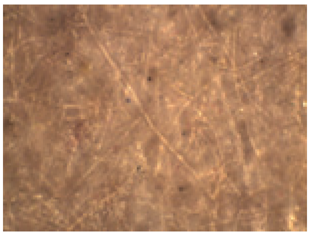

Figure 30. Specimen 5 (150 g/m^2).

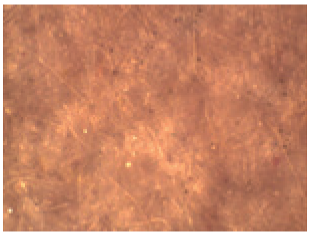

Figure 31. Specimen 6 (200 g/m^2).

of waste disposal with reuse decrease. White office paper sustains most of its original properties, even after reuse, which can be confirmed with presented results in this paper. Recycled office paper, or paper produced from secondary cellulose fibres, meets the required standards and expectations. Re-establishing recycling system and usage of recycled materials demands from employer's commitment and time. Primarily, to educate and familiarize users with a new regime of office paper usage (e.g. both side printing, smaller text size, printing only when needed, etc.). Purposeless handling with office paper, whose part are we all each and every day, both in office and home, should lead us at least to thinking of more efficient and economical way of using it, or even partial replace it with recycled office paper. Presented work has all the arguments in favour of recycling office paper.

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