Quality of fibres obtained from waste paper from the perspective of the circular economy

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Introduction

Waste paper is an important raw material that can be efficiently evaluated in accordance with the rules of the circular economy. In addition to the standard recycling of waste paper, it is of interest to increase its evaluation into new products. Cellulose fibres obtained from waste paper can be contaminated with additives that are used in paper production or are part of printing pigments, inks and adhesives. A higher degree of evaluation of cellulose fibres requires their higher purity. An important part of the paper consists of fillers of an inorganic nature (up to 28%) that replace paper fibres (Hubbe and Gill, 2016). The most commonly used fillers include calcium carbonate in both natural (limestone) and synthetic form (precipitated calcium carbonate – PCC). The literature lists up to 348 compounds that may be present in paper (Pivnenko et al., 2016). 157 potentially hazardous compounds have been identified in the paper. 133 chemical substances have been assigned to the printing industry, the majority of which are solvents and polymer resins used in inks, pigments, and dyes. Chemical compounds that cannot be assigned to either the paper industry or the printing industry could potentially be by-products or contaminants introduced into the production cycle through recycled paper (Pivnenko et al., 2016). The article aims to propose a technology that will be capable of removing additives, which will enable the broader usability of cellulose fibres in the application of circular economy principles.

Material and methods

Separated samples of waste paper (office paper, magazines, cartons) were obtained from SMOLO Co., which deals with waste management. The waste paper samples were cut into smaller pieces (about 1 cm) and minced. The possibility of using hydrochloric and acetic acid for calcite removal was verified (Kim et al., 2018). The X-ray diffraction method was used to identify the filler. The loss of Ca in the separated fibres was monitored by X-ray fluorescence. Calcium in the solution was determined according to the standard ČSN ISO 6058. The TD-GC/MS method (Gerstel, Muelheim an der Ruhr) was used to identify organic compounds.

Results and discussion

In the analysed samples of waste paper, identified additives include synthetic plasticisers, antioxidants, surfactants, flame retardants, crosslinking agents, organic pigments, slip agents, and pigments. Degradation products of plasticisers, precursors for the production of surfactants, photopolymers, dyes, polyurethane adhesives, pH adjustment agents, oxidising agents for dyes, solvents for dyes and plasticisers were also identified. A total of 57 organic compounds in the input samples were identified. Intermediates for dyes, inks, pigments, plasticisers and intermediates for plasticisers have the highest representation among the additives (Figure 1).

The largest amounts of additives were identified in office paper (8.75 g/kg), in cartons (3.41 g/kg) and the least in journals (1.67 g/kg). The concentration of additives decreases significantly through the fibre preparation process (washing by CH_3COOH).

Plasticisers in waste paper come mainly from dyes and pigments; they enhance plasticity in them. A total of 11 compounds were identified, including phthalates (DEHP and DBP). Treatment of waste paper in CH_3COOH reduced the concentration of plasticisers three times. The highest decreases in concentration were found for 1,3-benzenediol monobenzoate (about 35 times) and for bis(2-ethylhexyl)ester 2-butenedioic acid (22 times).

Antioxidants (components of paints, inks) in the waste office paper include Naugard 451 (87.2 mg/kg) and butylated hydroxytoluene (BHT, 12.02 mg/kg), which have been completely eliminated by acidic treatment. Crosslinking agents in office paper are represented by synthetic methylenediacrylamide (56.4 mg/kg). Crosslinking agents belong to the retention aids. Retention aids are used to improve the retention of fibres and fillers in paper pulp, thus reducing the amount of material lost during the papermaking process. Fibres obtained from office paper contain about 11 times lower concentrations of methylenediacrylamide (5 mg/kg) than the input waste office paper.

The flame retardants group accounts for 1.2 to 2.4% of the total sum of additives. In waste paper samples, the flame retardant 1-chloro-2-propanol phosphate (3:1) was identified at a concentration of 26-86 mg/kg. Treatment with CH_3COOH reduced its content by up to three times. In addition, the presence of the toxic bisphenol A and bisphenol S was demonstrated in the waste paper; they were fully removed by treatment. Mediators for producing paints, inks and pigments account for 5.2 to 27% of the total amount of additives. Treatment with CH_3COOH reduced the concentration of compounds contained in the fibres by up to 12 times.

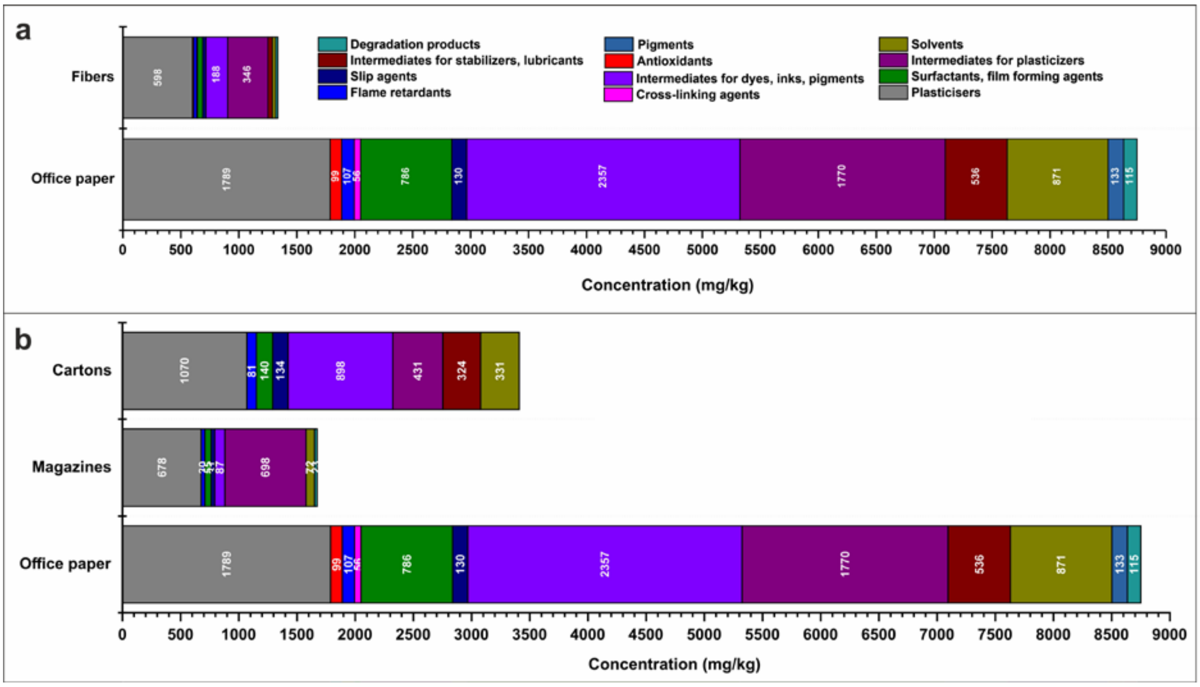

Figure 1. Comparison of additive concentrations in office paper and separated fibres (a); representation of additives in samples of waste paper (b).

Conclusions

After treatment with CH_3COOH, 40 compounds remained in the fibres, 34 compounds were removed, and 60 compounds were newly identified in the fibres. Their occurrence is likely related to their presence in precipitated calcium carbonate. They are released and attached to the fibres after the decay of the carbonates. After treatment with CH_3COOH, the concentration of additives in the fibres decreased by 85%. Yet, the fibres contain some dangerous compounds such as DEHP and DBP, which greatly restrict the subsequent use of fibres for the manufacture of day-care products and medical purposes but can be used in construction or as fuel.

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