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Investigation of Cotton Component Destruction in Cotton/Polyester Blended Textile Waste Materials

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The recycling technologies of textile industry waste usually are adjusted for materials manufactured of uniform fibers. Unfortunately, usually materials are manufactured of blended chemical and natural fibers to achieve better wearing properties, i. e. abrasion resistance, durability and etc. This paper presents investigation about the destruction of cotton component and easy separation from non-biodegradable polyester. The pre-treatment (soaking in aqueous solutions of reagents) was carried out at different temperatures for blended knitting yarn (50 % cotton / 50 % polyester) waste. The waste was pre-treated by aqueous solutions of reagents: $MgCl_2$; $Al_2(SO_4)_3$, $MgCl_2$ and $Al_2(SO_4)_3$ mixture, $MgCl_2$ and citric acid mixture at 20, 50, 90 and 130 °C. After the pre-treatment all samples were dried at 102 °C and heat-treated at different temperatures: 150, 160 and 180 °C. The investigation results showed that the highest degradation rate (95.47 %) of cotton component from 50 % cotton / 50 % polyester blended knitting yarn waste was achieved by using the pre-treatment at 20 °C temperature by aqueous solution of 20 g/l $MgCl_2$ and 4 g/l $Al_2(SO_4)_3$ mixture and heat-treatment of dry samples at 180 °C temperature.

Keywords: textiles, waste, recycling, fibers, destruction.

1. INTRODUCTION

Post-industrial or production textile waste handling is a complex issue; the solution of this problem could be recycling the textile waste into the suitable raw materials for manufacturing new textile products. Usually the recycling technologies of waste from textile industry are applied only for materials manufactured from uniform fibers [1].

The analyses of the textile waste generated in Lithuanian enterprises showed that the significant part of the waste (40.74 %) from textile, apparel and furniture manufacturing enterprises was blended polyester/cotton, wool/acrylic, cotton/acrylic and another non-identified blended waste [2]. The cotton and polyester fibers are two the most commonly used in textile products [3 – 5], because they are comfortable, practical and durable. The methods for separation pure components from cotton/polyester blended textile materials were intensively investigated by many researchers in the world [6 – 10], and some of them were realized in practice. In some cases the cotton fiber could be separated from polyester fiber, without damaging polyester: dissolving cotton component in the sulphuric acid [6] or by dispersing in the relatively benign solvent- ethylenediamine [8]; burning with the 150 g/l – 200 g/l aluminium sulphate [11 – 13]; treating with the glacial acetic acid and acetic anhydride in the presence of catalyst [14] or with the anhydrous hydrochloric acid gas and mechanical stirring [15]. The polyester component can be dissolved in the tetramethylene sulfone and separated by filtration from cellulose component [7]. From the ecological point of view, more eco-friendly method of destroying cotton component from cotton/polyester blended textile materials is the treatment by cellulolytic enzyme solutions [10, 16]. In the research [10] it was shown that the maximum degradation of cotton component in knitted cotton/polyester sample after 96 h of reaction at 50 ºC temperature with enzyme Econase CE aqueous solution was only 57 %. The investigation [16] demonstrated that in purpose to remove more than 80 % of cotton component from polyester/cotton blended fabrics it was needed the combined action of mechanical effects and high concentrations of cellulose enzyme. All mentioned methods of chemical separation of cotton/polyester blended materials into individual components have an ecological disadvantages (using strong acids and organic solvents), and in the case of using biomaterials – the high concentration of enzymes and long process time.

The purpose of this study was to investigate the destroying conditions of cotton component in knitting yarn waste by pre-treatment in following reagents aqueous solution: magnesium chloride ($MgCl_2$); mixture of $MgCl_2$ and aluminium sulphate ($Al_2(SO_4)_3$), mixture of $MgCl_2$ and citric acid. The pre-treatments were carried out at 20, 50, 90 and 130 °C and heat-treatments at 150, 160 and 180 °C temperatures.

2. EXPERIMENTAL DETAILS

2.1. Materials

Yarns. Non-dyed Ne 40/2 50 % cotton and 50 % polyester knitting waste yarns from weaving laboratory of Textile Institute of SRI Center for Physical Sciences and Technology were used.

Auxiliaries. $MgCl_2 \cdot 7H_2O$ (purity >99.0 %), $Al_2(SO_4)_3 \cdot 16H_2O$ (purity ≥98.0 %) and citric acid monohydrate (purity ≥99.5 %) from Sigma Co. were used for the destruction of cotton component in cotton/polyester blended waste yarns.

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2.2. Procedures

Treatment temperature and $MgCl_2/Al_2(SO_4)_3$ ratio on the decomposition quantity of cotton fibre. As refers in literature [11 – 13], the cotton component in cotton/polyester blended materials can be destroyed by strong mineral acids or their salts. The mentioned methods used for cotton component destruction are complicated because of ecological problems [17] rising due to the residues of strong acids and their salts in to the wastewater. As it is well known, the magnesium chloride is less toxic to plant life [18], because it acts like a classical Lewis acids (pH is neutral) [19].

Magnesium chloride in combination with a source of proton such as a citric acid, aluminum chloride, aluminum sulfate or ammonium chloride has a strong catalytic action and can be used for destruction of cellulosic fiber [19, 20].

Table 1. Concentrations of $MgCl_2$, $Al_2(SO_4)_3$, $MgCl_2/Al_2(SO_4)_3$ in aqueous solutions and parameters

Sample No.	Reagent	Concentration, g/l	Pre-treatment temperature, respectively, °C	Heat-treatment temperature, °C
1–4	$MgCl_2$	200	20 50 90 130	150
5–8	$MgCl_2$	200		160
9–12	$MgCl_2$	200		180
13–16	$Al_2(SO_4)_3$	200		150
17–20	$Al_2(SO_4)_3$	200		160
21–24	$Al_2(SO_4)_3$	200		180
25–28	$MgCl_2/$ $Al_2(SO_4)_3$	100/100		150
29–32	$MgCl_2/$ $Al_2(SO_4)_3$	100/100		160
33–36	$MgCl_2/$ $Al_2(SO_4)_3$	100/100		180

Waste yarns treatment. The 36 samples were investigated in this research. The weight of every sample was 10 g and the content of blended waste yarns was 50 % cotton / 50 % polyester. The pre-treatment of sample was done in the infrared laboratory dyeing apparatus "Ahiba Nuance®ECO" (Datacolor International, USA), at 20, 50, 90 and 130 °C temperatures in aqueous solutions of $MgCl_2$, $Al_2(SO_4)_3$ and $MgCl_2 / Al_2(SO_4)_3$ with concentrations indicated in Table 1. The bath modulus was M10 and treatment time was 30 minutes. After treatment all samples were rinsed with cold water, decomposed cotton fiber separated with a Brüchner funnel and residual of yarns dried in air-circulation drying oven „Memmert CELSIUS 2005" (Schwabach, Germany) at 102 °C till constant weight of sample was achieved, and finally samples were treated for 4 minutes in laboratory oven and steamer "TFOS IM 350" (Roaches International, England) at 150, 160 and 180 °C temperatures. The quantity of residual cotton fiber in treated samples was determined by quantitative chemical analysis. The accuracy of measurements is ±0.5 %.

Tests. The quantitative fiber analysis of cotton fibre in cotton/polyester blended yarns was determined by the Standard method LST EN ISO 1833-11: 2011.

3. RESULTS AND DISCUSSION

The experimental results presented in Fig. 1 – 4, show the relation between the chemical treatment parameters (pre-treatment and heat-treatment temperatures) and destruction of cotton component. The cotton/polyester blend knitting yarns were treated by aqueous solutions of $MgCl_2$, $Al_2(SO_4)_3$ and their mixture (50 % / 50 %) (see Table 1).

The research results show that in case of increasing the pre-treatment temperature, the destruction of cotton component depends on the nature of salt used. It is obvious that the destruction of cotton component is not highly influenced by pre-treatment temperature, when aqueous solutions of $Al_2(SO_4)_3$ and $MgCl_2 / Al_2(SO_4)_3$ mixture, diversely to the treatment of $MgCl_2$ aqueous solution, are used. The difference between the amounts of destroyed cotton component at 20, 50, 90 and 130 °C pre-treatment temperatures is not very significant when treating with mixture of 100 g/l $MgCl_2$ and 100 g/l $Al_2(SO_4)_3$ or 200 g/l $Al_2(SO_4)_3$ aqueous solutions, and varies from 61.61 % to 98.98 %. In this case, the optimal pre-treatment temperature could be 20 °C, when treating by aqueous solution of $MgCl_2/Al_2(SO_4)_3$ salts mixture (see Fig. 1).

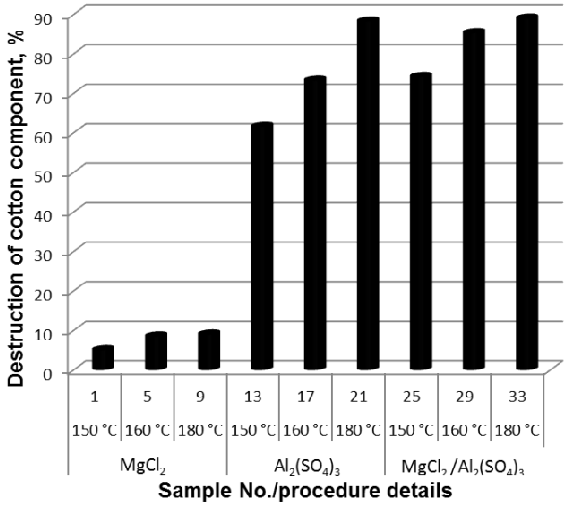

Fig. 1. The destruction of cotton component treating by different reagents at 20 °C pre-treatment temperature

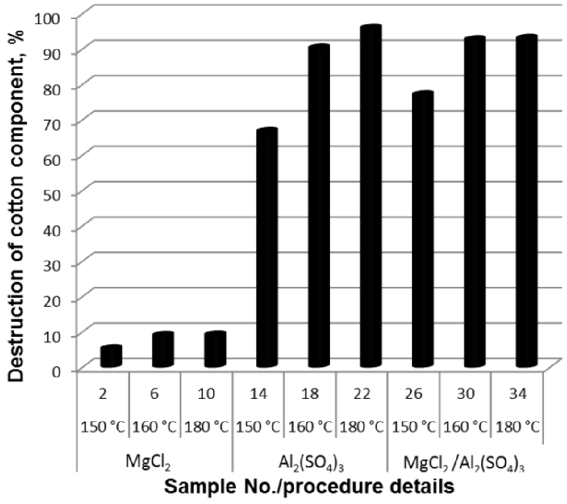

Fig. 2. The destruction of cotton component treating by different reagents at 50 °C pre-treatment temperature

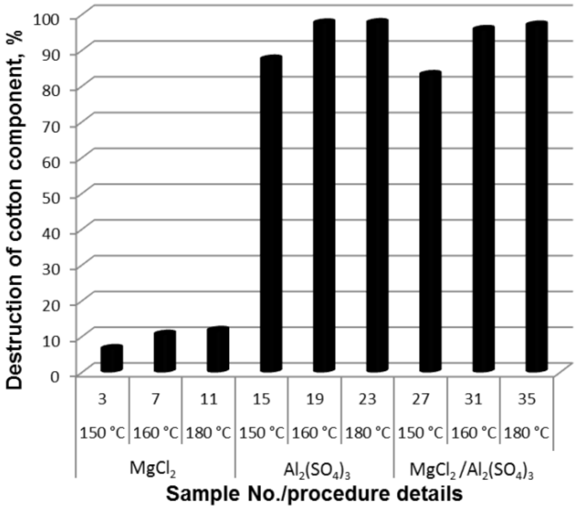

Fig. 3. The destruction of cotton component treating by different reagents at 90 °C pre-treatment temperature

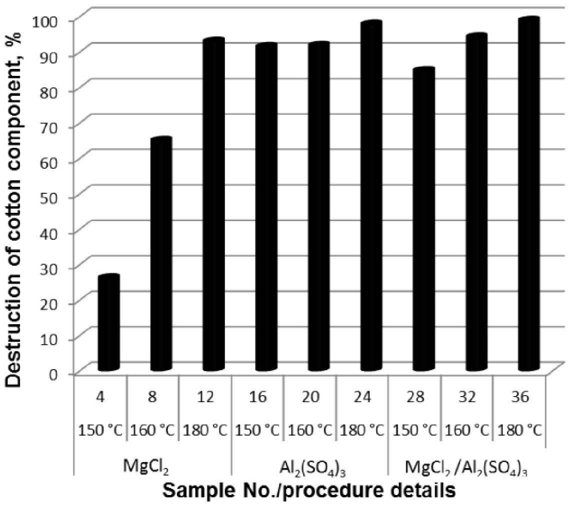

Fig. 4. The destruction of cotton component treating by different reagents at 130 °C pre-treatment temperature

The analyses of results presented in Fig. 1 – 4 allowed determining the optimal and effective destruction procedure parameters for 50 % cotton / 50 % polyester knitting waste yarns. The determined optimal parameters were: 20 °C pre-treatment temperature and 180 °C heat-treatment temperature when treating by aqueous solution of 100 g/l $MgCl_2$ and 100 g/l $Al_2(SO_4)_3$ salts mixture. These experimental conditions allowed achieving the 98.98 % destruction of cotton component in cotton/polyester blended knitting yarns waste.

The following investigation was carried out in purpose to find the optimal concentrations of $MgCl_2$ and $Al_2(SO_4)_3$ in solution for cotton component destroying. In Fig. 5 it was demonstrated that increasing of the $Al_2(SO_4)_3$ concentration in the aqueous solution, the destruction of cotton component was also increasing. It was noted that when the concentration of $Al_2(SO_4)_3$ achieves the 4 g/l, the destruction ratio was close to 100 % and here was no purpose to use higher concentration. Later on, the optimal concentration of the $MgCl_2$ was investigated.

Fig. 6 results showed that when the concentration of $MgCl_2$ was increased till 20 g/l, and the concentration of

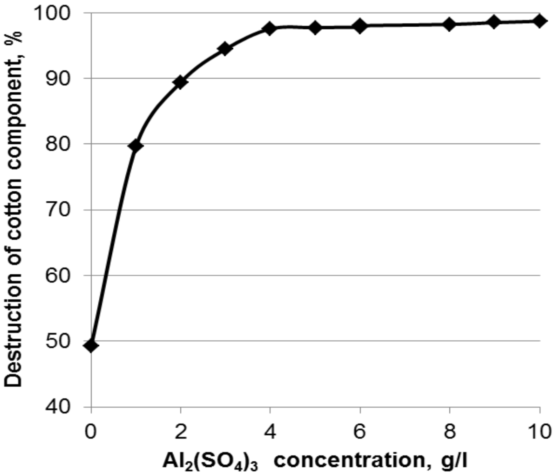

Fig. 5. The influence of the concentration of $Al_2(SO_4)_3$ on destruction of cotton component when the concentration of $MgCl_2$ is 200 g/l

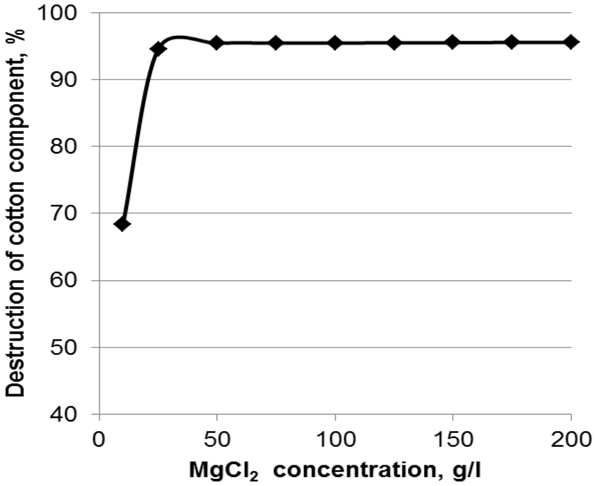

Fig. 6. The influence of the concentration of $MgCl_2$ on destruction of cotton component when the concentration of $Al_2(SO_4)_3$ is 4 g/l

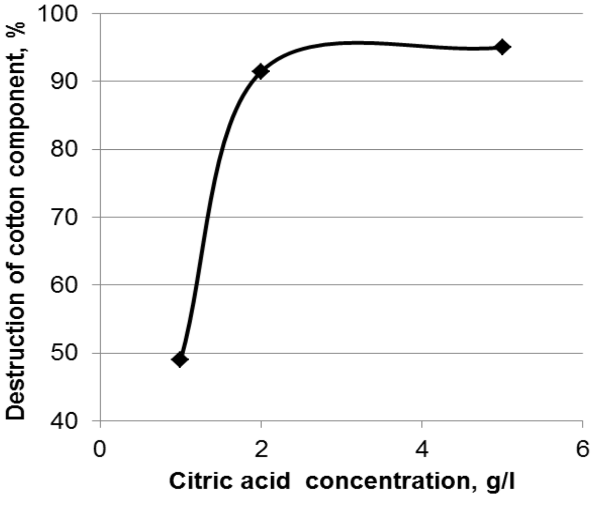

Fig. 7. The influence of the concentration of citric acid on destruction of cotton component when the concentration of $MgCl_2$ is 200 g/l

$Al_2(SO_4)_3$ was 4 g/l, the destruction of cotton component is 94 % – 95 %. This case showed that there was no aim to increase the concentration of the $MgCl_2$ in the aqueous $MgCl_2$ / $Al_2(SO_4)_3$ mixture solution.

The analyses were carried out in purpose to check the possibility to exchange the $Al_2(SO_4)_3$ with citric acid which is widely used in textile finishing processes [17]. In this case, the 50 % cotton and 50 % polyester knitting waste yarns were treated by aqueous solution of 200 g/l of $MgCl_2$ and 1 g/l – 4 g/l citric acid mixture at pre-treatment 130 °C and heat-treatment 180 °C temperatures. The results presented in Fig. 7 demonstrated that aqueous solution of 2 g/l citric acid and 200 g/l $MgCl_2$ mixture destroyed the 91.44 % of cotton component. The increase of citric acid amount in solution showed only marginal change in destruction ratio.

The investigation showed the main differences between the use of $MgCl_2$ / $Al_2(SO_4)_3$ and $MgCl_2$ / citric acid aqueous solutions for destroying cotton component. By treatment of cotton/polyester blended knitting yarns with aqueous solution of 20 g/l $MgCl_2$ and 4 g/l $Al_2(SO_4)_3$ at 20 °C temperature, higher (94 % – 95 %) destruction of cotton component was achieved by using less reagents and lower temperature, if compare with pre-treatment with aqueous solution of $MgCl_2$ and citric acid mixture mentioned above.

In the research works [11 – 13] the 150 g/l – 120 g/l of $Al_2(SO_4)_3$ was used for destroying cellulosic component, but we achieved the close effect while using lower amount of salts mixture (20 g/l $MgCl_2$ and 4 g/l $Al_2(SO_4)_3$).

4. CONCLUSIONS

1. The investigation results demonstrated that in order to achieve 94 % – 95 % destruction of cotton component the optimal concentration of $MgCl_2$ has to be 20 g/l and the concentration of $Al_2(SO_4)_3$ – 4 g/l. The pre-treatment temperature has to be 20 °C and heat-treatment temperature – 180 °C.
2. By treatment of cotton/polyester blended knitting yarns with aqueous solution of 200 g/l $MgCl_2$ and 2 g/l citric acid mixture at 130 °C, the 91.44 % destruction of cotton component were achieved by using higher concentration of $MgCl_2$ and higher pre-treatment temperature, in comparison to pre-treatment with aqueous solution of 20 g/l $MgCl_2$ and 4 g/l $Al_2(SO_4)_3$ at 20 °C temperature.
3. The destroyed cotton component can be easily separated from aqueous solutions of 20 g/l $MgCl_2$ and 4 g/l $Al_2(SO_4)_3$ by filtration with Brüchner funnel.

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