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on Fundamental and Applied Aspects of
Physical Chemistry

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and

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WASTE COTTON/POLYESTER YARN AS AN ADSORBENT FOR THE REMOVAL OF HEAVY METALS FROM WASTEWATER

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ABSTRACT
Waste cotton/polyester yarn was used for the removal of Pb(II), Cd(II), Cr(III) and As(V) ions from aqueous solution. In attempt to increase the adsorption efficiency, cotton/polyester yarn was modified by sodium hydroxide solution. Characterization of examined yarns was performed by scanning electron microscopy, Fourier transform infrared spectroscopy and streaming potential method for determination of the isoelectric point. It was shown that applied treatments slightly affected the surface acidity due to increased availability of ester groups and changes in cellulose-derived groups. These changes in surface chemistry of modified cotton/polyester yarns did not improve their adsorption capacity for Cd(II), Cr(III) and As(V) ions. However, both unmodified and modified waste cotton/polyester yarns could be used for efficient removal of lead ions from wastewater.

INTRODUCTION
Nowadays, the most widely used material for cloth manufacturing is cotton. In order to improve physical, mechanical and comfortable characteristics of clothing, decorative fabrics and textile products, mixture of cotton and polyester yarns are often used. The increase in textile production caused by frequent changes in fashion trends leads to the formation of large amounts of textile waste that can have a negative impact on the quality of the environment. Therefore, the possibility of reusing the waste textile, fibers and yarns are increasingly investigated in the past years. Following the general trend of using waste materials as adsorbents [1], in this work, cotton/polyester yarns obtained as a waste from textile industry, were used as cheap and efficient sorbent for removal of lead, chromium, cadmium and arsenic ions from wastewater.

MATERIAL AND METHODS
Waste cotton/polyester yarn (C/PES) was obtained from textile factory SIMPO Dekor (Serbia, Vranje). C/PES was modified by NaOH solutions, for one hour at room temperature, and two alkali treated samples were obtained: C/PES_{10} (10 % NaOH) and C/PES_{18} (18 % NaOH).

The morphological characteristics of yarn samples were assessed by scanning electron microscopy (Mira3, Tescan). FTIR spectra of the samples, within a range of 400-4000 cm^{-1}, were recorded using a Nicolet™ iS™ 10 FT-IR Spectrometer (ThermoFisherSCIENTIFIC). Zeta potential (ζ) of cotton yarn samples was measured using the streaming potential method (SurPASS electrokinetic analyzer, Anton Paar GmbH), as described in the literature [1]. Isoelectric point (IEP) was determined by extrapolation of experimental data.

Adsorption of Pb(II), Cd(II), Cr (III) and As(V) by unmodified and modified C/PES samples were performed from aqueous solutions, in the batch system at 25 ^{o}C. Fixed amount of unmodified and modified C/PES samples (0.02 g) was added in 20 cm^3 of metal ions solution at initial concentrations ranging from 100 to 1000 μg dm^{-3}, per each ion. Concentration of selected metal ions in the solution was measured by inductively coupled plasma-mass spectrometry (ICP-MS Agilent 7500e).

RESULTS AND DISCUSSION

The structure and surface morphology of C/PES sample, composed from cotton and PES components, is visible on Fig. 1a.

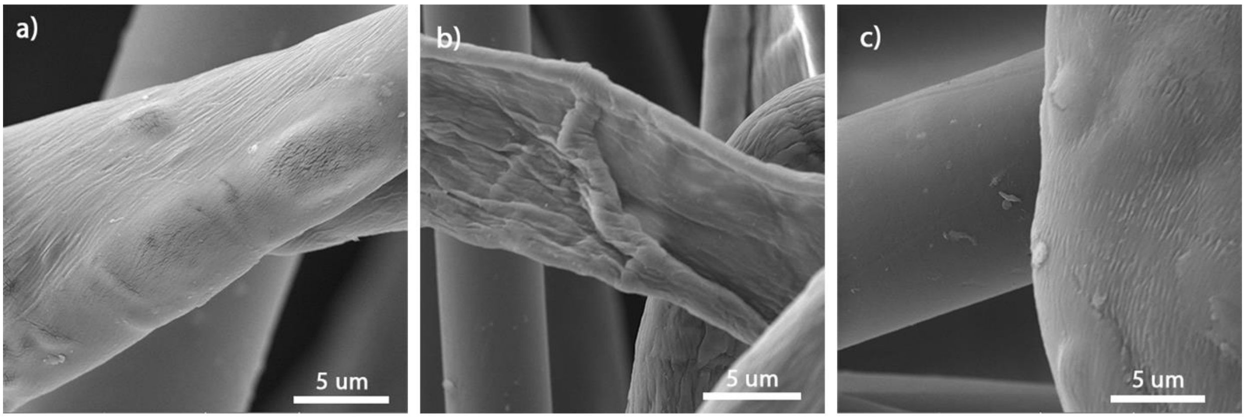

Figure 1. SEM photographs of a) C/PES, b) C/PES_{10} and c) C/PES_{18}

Cotton component consists from spirally twisted cotton fibers, with distinctly rough surface, featured by longitudinal cracks along the fiber. On the other hand, PES component is characterized by straight, untwisted, filament, with noticeably smooth surface. Applied treatments do not affect the morphology of modified C/PES samples (Fig. 1b and 1c).

FTIR spectra for unmodified and modified C/PES samples are shown in Fig. 2a. The wide band between 3350 and 3250 cm^{-1} is assignable to the stretching vibrations of O-H bond (hydroxyl groups), whereas the bands around 2920 and 2850 cm^{-1} are to be ascribed to asymmetric and symmetric C-H stretching vibrations, respectively.

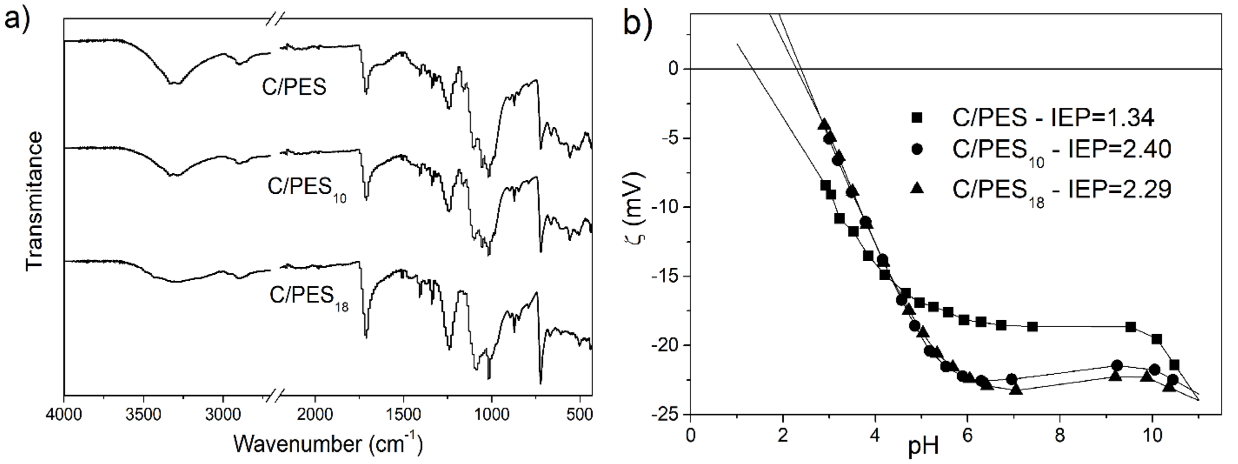

Figure 2. Characterization of C/PES samples: a) FTIR spectra and b) point of zero charge

The broad peak around 1630 cm^{-1} can be attributed to the aromatic skeletal vibration, or C=O stretching vibrations of carbonyl groups [2]. The bands in region 1150-1000 cm^{-1} are assigned to cellulose, indicating C-O and C-C stretching. Peaks at 1710 and 1240 cm^{-1} originated from ester group, while peak at 1505 cm^{-1} originated from aromatic systems in polyester chains [3].

Applied modification, and increase in NaOH concentration, lead to the increase in intensity of bands at 1710 and 1240 cm^{-1}, and alter the surface chemistry of cotton component (changes in the region 1150-1000 cm^{-1}). Applied treatments induce opening of the yarns structure, making ester groups more available. Increased accessibility of ester groups made surface less acidic, which is visible from increase in the IEP values (Fig. 2b.).

All C/PES samples showed high adsorption efficiency for lead ions, which were the most competitive (Fig. 3). However, increased accessibility of less acidic ester groups on the surface of C/PES_{10} and C/PES_{18} negatively affected the adsorption of less competitive ions (Cd(II), Cr (III) and As(V)). Therefore, the adsorption of heavy metals was studied through adsorption kinetics and isotherms using unmodified C/PES as adsorbent (Fig. 4).

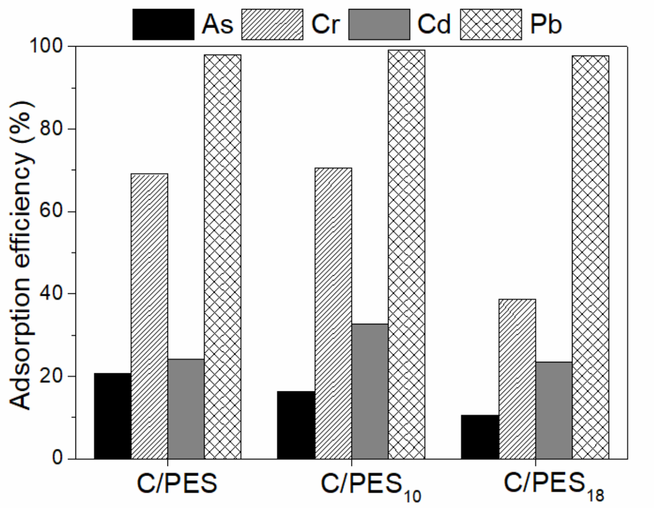

Figure 3. Adsorption efficiency of C/PES samples

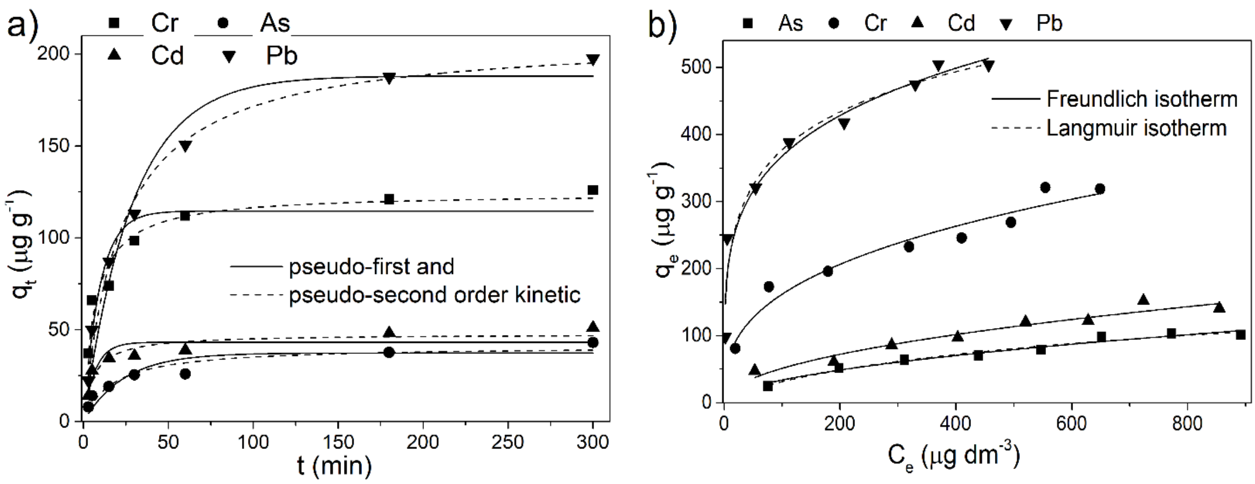

Figure 4. Effect of time (a) and initial concentration (b) on heavy metals adsorption onto C/PES sample

Adsorption of tested heavy metals on C/PES better fits with pseudo-second order kinetic model, suggesting that adsorption process is characterized by chemisorption. Adsorption equilibrium data showed equally good fitting with both, Freundlich and Langmuir isotherm models.

CONCLUSION

Chemical modification with NaOH opened the yarn structure, making its surface groups more available. This apparent increase in ester groups number, along with the alteration of cellulose surface chemistry from cotton component, changed the acidity of yarn surface. Applied treatments did not improve the capacity of C/PES yarns for adsorption of Cd(II), Cr (III) and As(V). Nevertheless, it has been shown that lead ions can be efficiently removed from wastewater by adsorption onto both, unmodified and modified waste cotton/polyester yarns.

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