



DYEING COTTON WITH BIFUNCTIONAL REACTIVE DYE IN SEA WATER

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ABSTRACT: *Traditional dyeing of textiles requires the use of a large amount of fresh water, which in combination with the use of large amounts of salt and auxiliaries contributes to significant environmental pollution. Using sea water as a textile dyeing medium is an innovative and environmentally friendly approach that addresses the challenges associated with conventional fresh water dyeing methods. The primary advantage of using sea water for textile dyeing is its high availability and high NaCl content. In this work the possibility of dyeing cotton with reactive bifunctional dye Bezaktiv red S-3B_{150%} in sea water was examined based on a comparative analysis with the results of dyeing in distilled water. Simulated and real sea water were used in the work. Dyeing was performed with 1% and 3% dye. Dyeing in a sea water bath was performed without the addition of NaCl or with a 38% (dark tone) and 50% (light tone) reduced amount of NaCl added to a distilled water bath. The results obtained by reflection spectrophotometry indicate that it is possible to dye cotton fabric with the selected reactive dye in a light shade in sea water because the color intensity (K/S) is approximately the same as the color intensity achieved with distilled water. And dyeing in a dark shade shows practical potential because the intensity of the color was lower by 30%, and it is possible to achieve better results by further improving the process (e.g. filtering water).*

Key words: *cotton, sea water, reactive dye, color intensity.*

BOJENJE PAMUKA BIFUNKCIONALNOM REAKTIVNOM BOJOM U MORSKOJ VODI

APSTRAKT: *Tradicionalno bojenje tekstila zahteva upotrebu velike količine slatke vode, koja u kombinaciji sa upotrebom velikih količina soli i pomoćnih sredstava doprinosi značajnom zagađenju životne sredine. Korišćenje morske vode kao medijuma za bojenje tekstila predstavlja inovativan i ekološki prihvatljiv pristup koji se bavi izazovima povezanih sa konvencionalnim slatkovodnim metodama bojenja. Primarna prednost upotrebe morske vode za bojenje tekstila je njena velika dostupnost i sadržaj velikih*



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količina NaCl. U ovom radu ispitana je mogućnost bojenja pamuka reaktivnom bifunkcionalnom bojom Bezaktiv red S-3B_{150%} u morskoj vodi na osnovu komparativne analize sa rezultatima bojenja u destilovanoj vodi. U radu je korišćena simulirana i prava morska voda. Bojenje je izvedeno sa 1% i 3% boje. Bojenje u kupatilu sa morskom vodom izvedeno je bez dodatka NaCl ili sa 38% (tamni ton) i 50% (svetli ton) smanjenom količinom NaCl koja se dodaje u kupatilu sa destilovanom vodom.

Rezultati dobijeni refleksionom spektrofotometrijom ukazuju da je moguće bojiti pamučnu tkaninu izabranom reaktivnom bojom u svetloj nijansi u morskoj vodi jer je intenzitet boje (K/S) približno isti kao intenzitet boje postignut destilovanom vodom. I bojenje u tamnoj nijansi pokazuje praktični potencijal jer je intenzitet boje bio manji za 30%, i moguće je daljim poboljšanjem procesa (npr. filtriranjem vode) postići bolje rezultate.

Ključne reči: pamuk, morska voda, reaktivna boja, intenzitet obojenja.

1. INTRODUCTION

Clothing color plays a key role in the fashion industry, as it is the first feature consumers notice about a garment. Textile dyeing is an important stage of the technological process of textile production that consumes large amounts of water, chemicals and energy. In the textile industry, the current dyeing practice is problematic due to intensive water consumption and pollution. Cotton dyeing is particularly water intensive, as about 125 liters of water can be consumed per kilogram of cotton fibers for dyeing and finishing [1]. This water is returned to nature as toxic waste, which contains residual dyes and dangerous chemicals. One billion USD worth of dyeing is lost annually to waste water due to inefficient dyeing and finishing processes [2]. Were identified 72 toxic substances in the waste water from the textile dyehouse, 30 of which cannot be removed. Salts make up close to 50% of pollution and contribute the most to high values for total dissolved solids (TDS), biochemical oxygen consumption (BOD) and chemical oxygen consumption (COD) [3]. Water covers about 71 % of our planet's surface, but only 3,5% of all water on Earth is fresh water and most of it is frozen in the polar ice caps. Ground water accounts for 31% of the total fresh water, which is not easily accessible. The most accessible form of fresh water is found in lakes, rivers and reservoirs and it comprises only 0,3% of the total fresh water resource [4]. More recently, sea water has been studied as a possible processing medium for cotton dyeing, as it contains large amounts of inorganic salts. Ferreira et al. recently used sea water as an alternative for dyeing with reactive dyes [5]. They used colors of different functional groups and concentrations of 0,1% to 5% by weight of the material. In the sea water bath, NaCl was added only in the three highest concentrations. Samples dyed in a light shade (0,1%) had a higher intensity when dyed in sea water. In other concentrations, a higher intensity of coloring was achieved in distilled water, which led the authors to the conclusion that it is necessary to improve the process of using sea water for better results. Recently, sea water has been used for dyeing cotton and polyester fabrics [6]. The use of sea water in the dyeing of these fabrics contributed to a greater intensity of color on cotton by 15% and polyester by 3%. The aim of this work is to study the possibility of using sea water as a processing medium for dyeing cotton with a bifunctional reactive dye.

The assessment of the usability of sea water as a suitable medium for dyeing was carried out on the basis of the comparative quality of cotton dyeing in distilled water, simulated sea water and real sea water.

2. EXPERIMENTAL PART

2.1. Material and working methods

In the experiment, fabric samples of 100% cotton, surface weight 220 g/m², were dyed. The fabric is industrially prepared for dyeing. The samples for dyeing had a mass of 3 g. The volume of the bath was 160 cm³. The following chemicals were used in the work: Bezaktiv red S-3B_{150%}, bifunctional reactive dye (VS/MCT, Bezema, Switzerland), NaCl – salt, agent for increasing dye exhaustion, Na₂CO₃ – salt, agent for regulating the pH of the solution. Dyeing was performed using in Ahiba apparatus (TYPE G7B) in glass cuvettes with vertical movement of the material. The dye concentration was 1 and 3% by weight of the material, NaCl concentration 0-80 g/dm³ and Na₂CO₃ concentration 10 and 20 g/dm³. The dyeing solution formulations and sample designations are shown in table 1. The pH of the bath was 10,5 - 11. Dyeing was performed in distilled, simulated sea water and real sea water. Table 1 contains sample designations depending on the dyeing bath formulations. Dyeing was performed using the all-in method, according to the dyeing profile shown in figure 1.

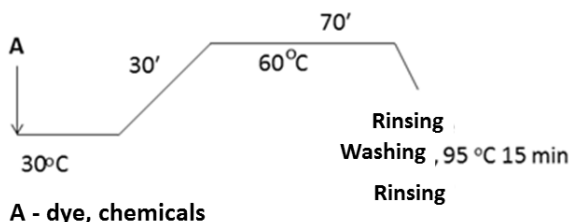


Figure 1: Dyeing profile of dye Bezaktiv red S-3B_{150%}

Table 1: Sample designations and dye bath composition

Designations of samples	Water	Conc. dye, %	NaCl, g/dm ³	Na ₂ CO ₃ , g/dm ³
P1	DW	1	50	10
P2	SMW	1	25	10
P3	DW	3	80	20
P4	SMW	3	50	20
P5	PMW	1	0	10
P6	PMW	1	25	10
P7	PMW	3	0	20
P8	PMW	3	50	20

DW- distilled water; SMW – simulated sea water; PMW – real sea water (Aegean Sea)

The composition of the simulated sea water is presented in [7]. The reflectance of the samples at wavelengths of 400–700 nm was measured using a Spectraflash SF600X reflection spectrophotometer (Datacolor – USA) and the CIELab color coordinates were determined.

Based on the reflection value at the wavelength of maximum adsorption for each sample, the color intensity (K/S) was calculated according to the Kubelka-Munk equation:

$$\frac{K}{S} = \frac{(1 - R)^2}{2R}$$

The wavelength of maximum adsorption for Bezaktiv red S-3B150% is 550 nm.

Based on the color intensity before and after soaping, the degree of dye fixation, F(%), was

determined using the following equation:

$$F = \left(\frac{\frac{K}{S}_T}{\frac{K}{S}_0} \right) \cdot 100$$

where the subscript *T* refers to the fabric treated in a soap solution, and the subscript *0* to the untreated fabric, immediately after dyeing.

3. RESULTS AND DISCUSSION

Figure 1 shows the reflectance diagrams of cotton fabrics for different dye concentrations. The area below the reflection curve shows the reflected energy, and the area above the reflection curve shows the absorption energy. Samples dyed with 1% Bezaktiv red S-3B150% (image a) have higher reflection energy, compared to samples dyed with 3% dye (image b). In the entire interval of wave lengths, the samples dyed with the standard recipe in distilled water have the lowest reflection energy. This color has minimum absorption in the sector of complementary green colors, i.e. at 550 nm.

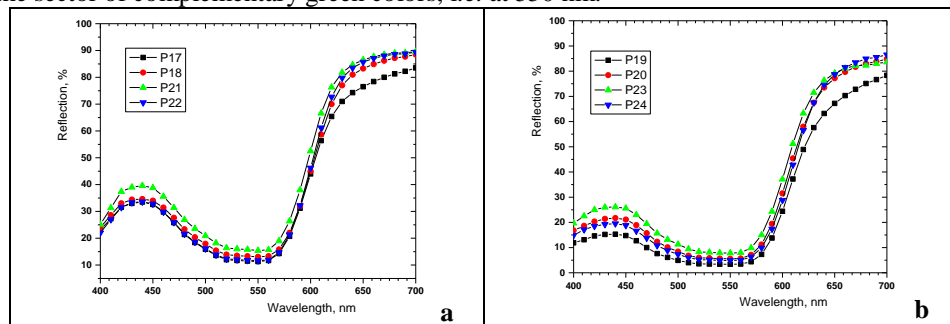


Figure 1: Reflectance of cotton fabric samples dyed with Bezaktiv red S-3B150% 1% (a); and 3% (b)

L^* is the vertical coordinate of the three-dimensional CIELab system and shows the similarity of chromatic colors with achromatic colors. The higher the value of L^* , the more similar a chromatic color is to white – an achromatic color. Compared to the sample dyed

in distilled water with a standard recipe - sample P1 ($c=1\%$), the samples dyed in sea water - samples P2, P5 and P6, have higher values of the L^* coordinate (figure 2).

On samples dyed in sea water, the values of the lightness coordinate L^* are 10-15% higher than on the sample dyed in distilled water, for the dyeing system with 3% Bezaktiv red S-3B₁₅₀%. Sample P7 dyed in real sea water without the addition of NaCl has the highest lightness value. And visually in figure 3 it can be seen that sample P7 has the tone of the lowest intensity.

All samples dyed in simulated or real sea water have lower intensity compared to samples dyed in distilled water. In the process of dyeing cotton with reactive dyes, the presence of NaCl is necessary in order to transfer the color from the solution to the fiber. The presence of NaCl in the bath manifests itself as an increased exhaustion of dye from the technological solution, i.e. as a higher color intensity on fabric samples.

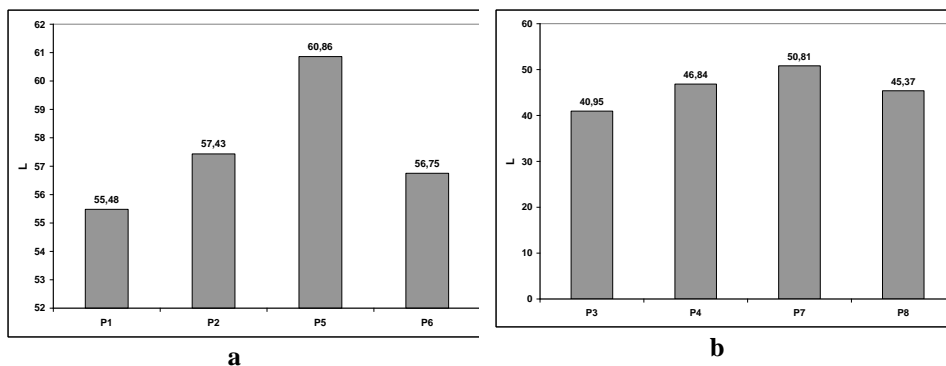


Figure 2: Color lightness L^* of samples dyed with Bezaktiv red S-3B₁₅₀ 1% (a); and 3% (b)



P3



P4



Figure 3: Photographs of samples dyed with 3% Bezaktiv red S-3B_{150%}

Samples dyed in simulated sea water had about 15% (for a lighter tone, Fig. 4a) and about 40% less intensity (for a darker tone, Fig. 4b) of color, due to a reduced concentration of NaCl by 50% and 38%, respectively, compared to the standard recipes. Samples P5 and P7 that were dyed in a bath with real sea water and without the addition of NaCl (only Na₂CO₃ added) have by far the largest drop in color intensity, namely 33% (for a lighter tone) and 60% (for a darker tone). For the practice of dyeing, the approach of dyeing in real sea water with a reduced concentration of NaCl makes sense. It is possible to dye a light tone in real seawater with 50% less NaCl (compared to the standard recipe) because the color intensity on the cotton fabric is only 4% lower, compared to the sample dyed in distilled water. When dyeing in a shade with 3% color, the color intensity of the sample is lower by 33% (conc. NaCl lower by 38%, sample P8).

The degree of fixation *F*, the values of which are shown in Table 2, shows what proportion of the total dye consumed is fixed to cotton cellulose by establishing a covalent bond. From the results shown, it can be assumed that the change in the process medium in the studied dyeing system had no effect on the covalent fixation of the dye, i.e. the reaction of reactive groups with the ionized hydroxyl group of cellulose. The values for the degree of fixation of reactive dye *F* had approximate values.

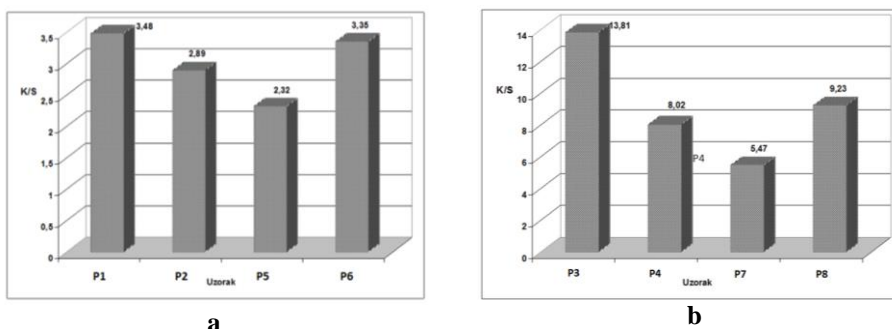


Figure 4: Color intensity samples dyed with Bezaktiv red S-3B_{150%} 1% (a); and 3% (b)

Table 2: Degree of fixation (F) of dye Bezaktiv red S-3B_{150%} on samples of cotton fabric

Designations of samples	F, %
P1	85
P2	84
P3	81
P4	86
P5	86
P6	83
P7	80
P8	82

4. CONCLUSION

By dyeing textiles in sea water, it is possible to reduce the amount of sodium chloride added to the dyeing bath, because sea water is a natural resource that contains salt. The results obtained by reflection spectrophotometry indicate that it is possible to dye cotton fabric with the selected bifunctional reactive dye Bezaktiv red S-3B_{150%} in light shades with a salt amount that is 50% lower than in standard dyeing, since under this condition approximately the same dyeing intensity was achieved. Dyeing in darker shades also shows practical potential because when the salt concentration (NaCl) is reduced to 38%, the color intensity is reduced by 1/3 of the standard intensity. Further process improvement is needed for better results. This involves preparing the water to reduce its hardness and possibly removing some chemicals – e.g. by filtration – that affect the interaction of dyes with fibers.

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