

## The Antimicrobial Effects of Zycrobial on Cotton and Cotton/Polyester Blend Fabrics in the Presence of the Different Dyes and Treatments

<sup>1</sup>Farzaneh Jahangiri, <sup>2</sup>Ali Ashjarian and <sup>1</sup>Behnaz Mehravani

<sup>1</sup>Department of Textile and Chemistry, Shahre-Rey Branch, Islamic Azad University, Tehran, Iran

<sup>2</sup>Department of Chemistry, Faculty Member of Textile, Shahre-Rey Branch,  
Islamic Azad University from Young Research Club, Tehran, Iran

**Abstract:** The growth of microorganisms on textiles inflicts a range of unwanted effects not only on the textile itself but also on the wearer. Humans' need for personal health and hygienic clothing has led to creation of a great number of antimicrobial textile products. In this research, an attempt has been made to investigate biological effects of Zycrobial (2-Hydroxyethoxydimethoxysilyl) as quaternary ammonium compound on cotton and cotton/polyester blend fabrics in presence of various dyes such as reactive, direct, vat and disperse. The effects of plasma on antimicrobial properties of dyed fabrics were determined in different conditions. The laundering stability and persistence of antibacterial activities of the treated fabrics were compared. The effect of Zycrobial was assessed on some physical features such as mechanicals properties, stiffness of fabric, wrinkle recovery resistance and moisture absorption. The results of experiments demonstrated different antibacterial properties of the samples in various dyes and finishing conditions in presence of two types of bacteria (E.coli AATCC 8099 and S.aureus AATCC 6538). Furthermore, this substance didn't have any impression on some physical properties like strength but in others such as stiffness, wrinkle recovery resistance and moisture was proved to be effective.

**Key words:** Cotton • Polyester • Antimicrobial • Plasma • Zycrobial

### INTRODUCTION

The biodeterioration of textile fibers caused by microorganisms including bacteria, fungi and algae present in the air, water and soil can cause multiple problems for textile products. Biodeterioration can lead an unpleasant smell and colored stains. Changes in the textile colors and in the textile mechanical properties such as the breaking strength, elongation and elasticity negatively affect the applicability value of textiles from a hygienic and aesthetic point of view [1,2]. In the last few decades, prevention of microbial attacks on textile and wearers of textile materials has become increasingly important to consumers and textile producers. For instance, a market study in Germany revealed a steady increase in the demand for antimicrobial fabrics [3]. Therefore, with a rising interest in personal health and hygiene, textiles with antimicrobial properties are becoming an increasingly desirable aim of textile manufactures [4].

Several different types of antimicrobial agents such as oxidizing agents, coagulants, diphenyl ether (bis-phenyl) derivatives, heavy Metals and metallic compounds, chitosan and quaternary ammonium compounds (QACs) are used in the textile industry to confer antimicrobial properties [4]. Among them, QACs, chains of 12-18 carbon atoms, have been widely used as cationic disinfectants or biocide coating to prevent the growth of microorganisms on the surface of materials including fibers, paints filters and packing films. These compounds carry a positive charge at the N atom in solution and inflict a variety of detrimental effects on microbes as well as damage cell membranes, denaturation proteins and disrupt of the cell structure [5]. A significantly different and much more unique antimicrobial technology used in the nonwovens and building construction industries does not leach but instead remains permanently affixed to the surface on which it is applied. Applied in a single stage of the wet

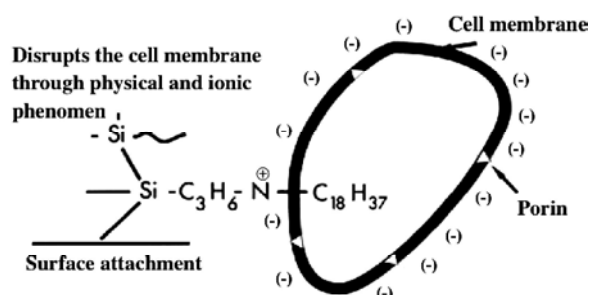


Fig. 1: Chemical bonded mechanism

finish process, the attachment of this technology to surfaces involves two means. First and most important is a very rapid process, which coats the substrate (fabric, fiber, etc.) with the cationic species (physisorption) one molecule deep. This is an ion exchange process by which the action of the silane QACs replaces protons from water or chemicals on the surface. The second mechanism is unique to materials such as silane QACs. In this case, the silanol allows for covalent bonding to receptive surfaces to occur (chemisorption). This bonding to the substrate is then rendered even more durable by the silanol functionality, which enables them to homopolymerize. After they have coated the surface in this manner, they become virtually irremovable, even on surfaces with which they cannot react covalently (Figure 1) [6].

In this research, Zycrobial which is a poly siloxan based cationic QAC is used for retentive antimicrobial and anti-odor finish on cotton and polyester substrates. Cotton and cotton/ polyester blend fabrics is used in this study because they are frequently used fabric for scrub suits, lab uniforms and many medical and common textiles. The selection of these fibers ensured sufficient comfort resulting mainly from the use of cotton fibers as well as suitable mechanical properties such as the tensile strength characteristic of synthetic fibers [7]. For dyeing cotton/polyester blend fabrics, Vat, reactive, or direct dyes may be used for the cotton component after fixation of the disperse dye on the polyester component [8]. Existence of these dyes in fabric structure can be effective on others finishing that have been done on the fabric. So the get of this study is examination of antibacterial properties of Zycrobial in presence of different kinds of dyes in diverse situations such as plasma treated or untreated, washing procedure and also investigation of every impression of this substance that cause to change in the physical properties such as mechanical properties, stiffness of fabric, wrinkle recovery angle and moisture absorption.

## MATERIALS AND MATHODS

**Swatches and Finishing Agent:** In this study two fabrics constructed from different raw materials were used: 100% cotton (CO) fabric with a weight of 138 g/m<sup>2</sup> and blend fabric of cotton/polyester (CO/PET) composed of 60% CO (thread of weft) and 40% polyester (thread of warp) with a weight of 120 g/m<sup>2</sup>, 100% cotton (CO) staple yarn with 10 den and 100% polyester (PET) filament yarn with 100 micro [2].

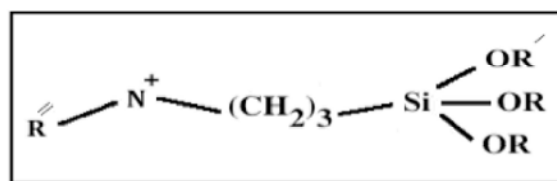
The antimicrobial agent, Zycrobial was obtained from Exire sharghe Mashhad Ltd, the representative of Zydex Co. in Iran. (It is based on 2-Hydroxyethoxy dimethoxysilyl, shown in figure 2):

**Dyes:** The characteristics and chemical structures of the dyes are showed in Table 1 and Figure 3(a-d):

**Microorganism:** The bacterium was provided by the microbial bank of Tarbiat modarres university of Tehran: gram - negative (*Escherichia coli* AATCC8099) and gram - positive (*staphylococcus aureus* AATCC6538).

**Nomenclature:** The explanations of signs which are used in the present study are to be found in the following description:

Z, Zycrobial treated; Z+10w, Zycrobial treated then 10 times washed; P+Z, plasma then Zycrobial treated; P+Z+10w, first plasma then Zycrobial treated and at last 10 times washed; D, R & V, dyed fabrics with direct, reactive and vat dyes.



(2-Hydroxyethoxydimethoxysilyl)  
Octadecyldimethyl Ammonium Chlorid

Fig. 2: The chemical structure of Zycrobial

Table 1: Name, color index and the manufacture of the dyes

Commercial name	C.I	Company
BASF 58	24400 Direct Blue 15	T.H.C
NovaticbluBc	69825 Vat Blue 6	Atic industrial
Remazole Brilliant		
blue special	61200 Reactive 19	HOE AG
Serilene blue RL	63285 Disperse blue 56	YCL

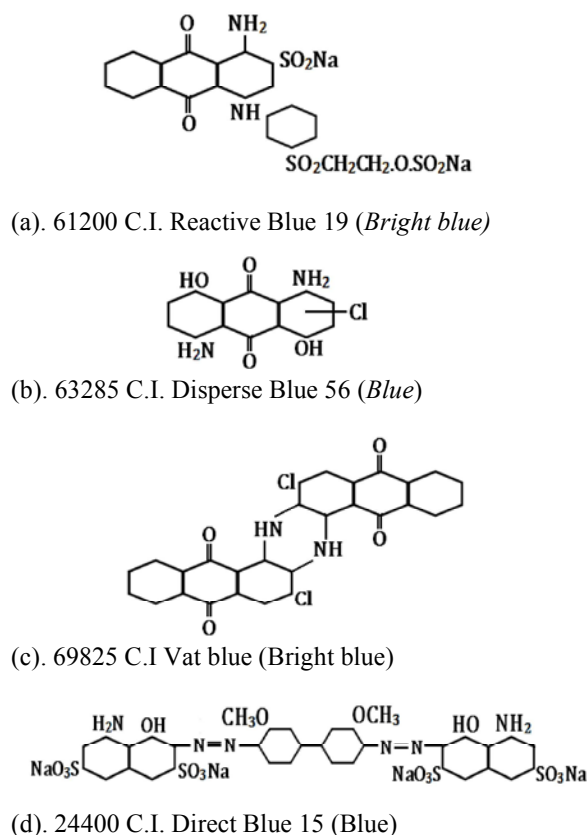


Fig. 3(a-d): Chemical structures of dyes by C.I number

## Methods

**Dyeing:** Cotton fabrics dyed with direct, reactive and vat dyes. The polyester part of Cotton/polyester blend fabrics dyed with disperse dye and cotton part with direct, reactive and vat dyes in separate baths.

**Plasma Treatment:** The fabric samples with dimensions of 5cm\*5cm were produced using an injection molding machine. The samples were laid on stainless steel substrates and inserted into the plasma immersion ion implanter. The O<sub>2</sub> plasma treatment was performed in the optimal conditions based on many experiments: bias voltage = -12 Kv, voltage pulse width = 20 μs, pulsing frequency = 30 Hz, gas flow= 35 seem, RF power = 1000w and treatment time = 30 min [9].

**Antibacterial Treatment:** In order to finish antibacterial property as per gram weight of goods, 1.5g water and as 3% ratio of weight of goods, Zycrobial were added to the bath, then specimen was entered into the bath and immersed for 10 minutes and finally it was dried for 5 minutes in the oven with a temperature of 90°C.

**Washing Procedure:** The treated samples were washed repetitively 10 times according to AATCC test method 61-1994. The treated samples were then evaluated for antimicrobial activity before and after washing [10, 11].

**Antibacterial Activity Evaluation:** The antimicrobial activity of the treated and untreated samples was quantitatively evaluated against both gram-positive (S.aureus-AATCC6538) and gram-negative (E.coli-AATCC 8099) bacteria according to the AATCC test method 100-2004. The percentage of the reduction of bacteria was calculated by following formulas:

$$R = (B-A) / B * 100\%$$

Where, R = % reduction, A = number of bacteria recovered from the treated specimen after 24 hr, B = number of bacteria recovered from the untreated specimen after 24 hr [12-14].

**Color Strength:** The color strength (K/S) of dyes fabric was assessed using Kubeka-Munk equation:

$$K/S = (1 - R)^2 / 2R$$

Where K and R are the absorption coefficient, scattering coefficient and reflectance, respectively [1].

**Physical Tests:** The wrinkle recovery angle (WRA) was measured according to AATCC test method 66-1989 by Shirley apparatus [15]. Some mechanical properties such as tenacity, elongation at rupture, force at rupture and initial modulus of the untreated and treated yarns were measured, according to ASTM D5030 by Testometric M500-25 CT [16]. Stiffness of fabrics was measured according to ASTM D1388 by Shirley apparatus. To determine the wicking rate, samples were cut (in ribbon shape) with dimensions of 170 mm by 25 mm and placed straight in a beaker containing distilled water. The height of wicked water in different times (1, 2 and 10 min) was recorded as the wicking ability factor. Each test was repeated three times and the mean value was reported [17].

## RESULTS AND DISCUSSION

**The Effect of Different Kinds of Dyes on Antibacterial Properties:** To investigate the effect of different dyes on the antibacterial activities of Zycrobial, first cotton and CO/PET fabric samples corresponding to the description

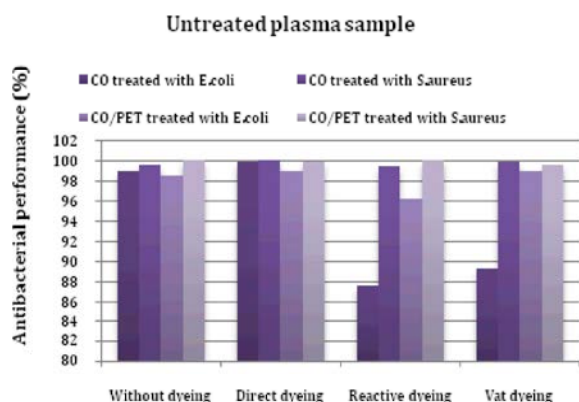


Fig. 4: Effect of different kinds of dyes on antibacterial activity of Zycrobal against two types of bacteria E.coli&S.aureus

recipe (in part 3.1) were dyed then treated with Zycrobal according to the prescription in part 3.3. Finally, their antibacterial activity was evaluated against two kinds of bacteria E.coli and S.aureus according to AATCC test method 100 - 2004 and shown in figure 4 (according to the antibacterial performance percentage). The results indicate that in cotton fabrics several dyeing may have different effects on the antibacterial property of a complementary material. Direct dyeing increases antibacterial property against two types of bacteria called E.coli and S.aureus; meanwhile, vat dyeing increases this property against S.aureus bacteria while decreasing it against E.coli bacteria. On the other hand, reactive dyeing decreases the total antibacterial property. It is to be noted that antibacterial property in CO/PET fabrics is different i.e. dyeing materials have no effect on the antibacterial property against S.aureus bacteria. Conversely, studying antibacterial property of CO/PET specimens against E.coli bacteria, it is observed that reactive dyeing decreases the antibacterial property in comparison to the other types of dyeing materials.

**The Effect of Plasma Treatment:** The plasma treatment effects on antibacterial activity of raw and dyed fabrics are shown in Figures (5-8) according to the antibacterial performance percentage. According to the obtained data it is observed that existence of plasma increases antibacterial property of specimens both in the presence or absence of different dyeing methods. In addition, provided that the specimens were washed for 10 times, the antibacterial property of specimens that were treated with plasma is higher in comparison to the other specimens that were not treated with plasma.

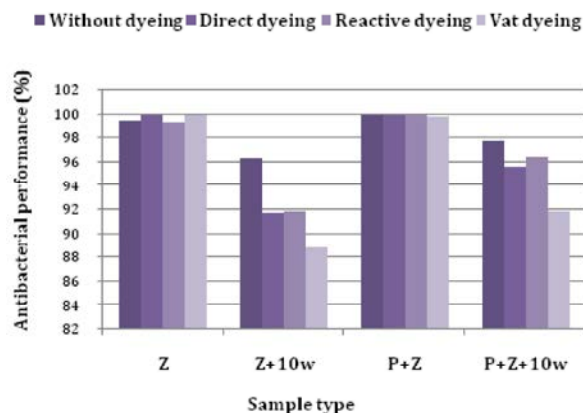


Fig. 5: Antibacterial activity of simultaneous dyed and treated cotton fabrics against Gram-positive bacteria (S.aureus AATCC 6538)

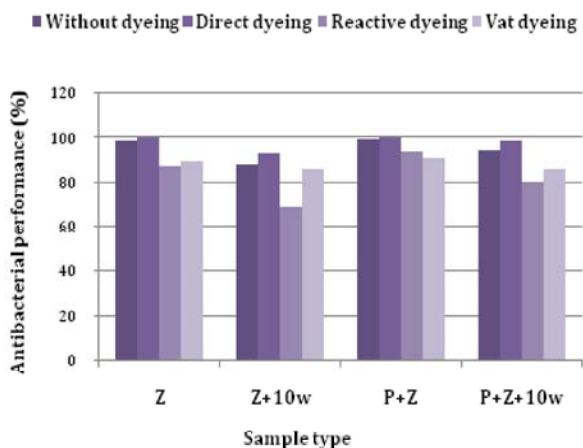


Fig. 6: Antibacterial activity of simultaneous dyed and treated cotton fabrics against Gram-negative bacteria (Escherichia coli AATCC8099)

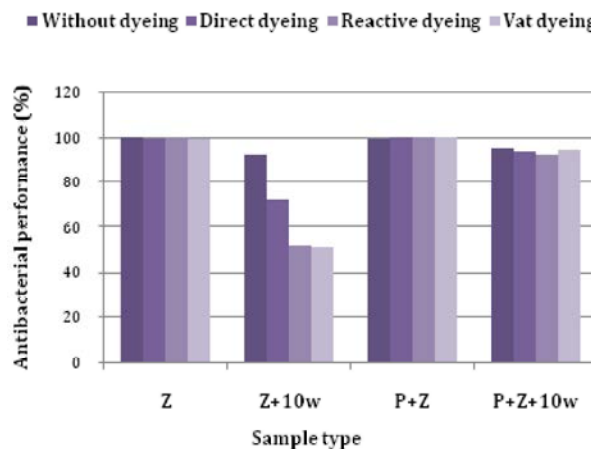


Fig. 7: Antibacterial activity of simultaneous dyed and treated CO/PET fabrics on Gram-positive bacteria (S.aureus AATCC 6538)

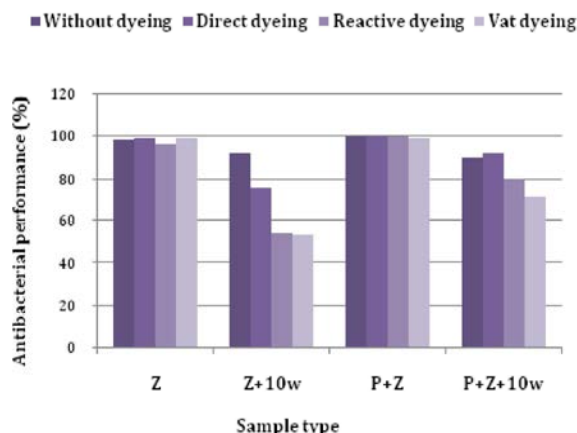


Fig. 8: Antibacterial activity of simultaneous dyed and treated CO/PET fabrics on Gram-negative bacteria (*Escherichia coli* AATCC8099)

**The Effect of Washing Procedure:** The biocide can be gradually lost during the use and washing of the textile [18]. For the sake of inspection of repetitious washing procedures effects on antibacterial activity of Zycrobal, all of the treated samples in different conditions were washed repetitively 10 times then their antibacterial activities were calculated. According to the obtained data, it is observed that the repeated washing procedure has a negative effect on Zycrobal antibacterial material especially if different dyeing materials are used. Moreover, it is observed that there is a larger decrease in the antibacterial property after 10 times washing in comparison to the conditions where the specimen does not undergo dyeing. However, provided that the specimens have been treated with plasma, the antibacterial property has a smaller decrease as a result of the repeated washings. Washing procedure effects on antimicrobial activity of dyed fabrics are shown in (5-8).

**The Effect of the Treated Fabrics on Two Kinds of Bacteria:** This section deals with studying antibacterial property of Zycrobal on two types of positive gram and negative gram bacteria. According to the data, it is observed that the antibacterial property of Zycrobal on *Staphylococcus* positive gram bacteria is higher in comparison to *E.coli* negative gram. The Figures (5-8) show the antimicrobial activity of dyed and non dyed fabrics.

**The Effect of Zycrobalon K/S Values of Fabrics:** K/S values of dyed CO and CO/PET fabrics are calculated according to Kubeka-Munk formula in  $\lambda_{\max}$ .

Table 2: K/S values of cotton fabrics dyed in  $\lambda_{\max}$

Dyes	Without				
	Zycrobal	Z	Z+10w	P+Z	P+Z+10w
Direct	3.185	3.191	2.833	3.232	2.719
Reactive	0.862	0.818	0.753	0.780	0.654
Vat	0.892	0.944	0.849	1.018	0.850

Table 3: K/S values of CO/PET fabrics dyed in  $\lambda_{\max}$

Dyes	Without				
	Zycrobal	Z	Z+10w	P+Z	P+Z+10w
Direct	7.009	6.850	5.912	6.322	5
Reactive	1.796	1.758	1.514	1.763	1.436
Vat	2.832	2.883	2.834	2.948	2.363

Table 4: Mechanical properties of treated and untreated cotton and polyester yarn samples

The types of Yarn samples	Tenacity (g/dTex*10)	Initial Modulus (g/dTex)	Elongation @ rupture (mm)	Force @ rupture (KgF*100)
Untreated CO	9.89	21.67	12.84	19.7
Treated CO	15.71	24.81	16.26	17.4
Untreated PET	31.57	14.26	68.38	35
Treated PET	35	14.24	88.53	38.7

Considering the obtained data in Tables 2 and 3, it is found that Zycrobal doesn't have any adverse effects on the color shades of fabrics tested and doesn't construct any alteration on it.

**The Effect of Zycrobal on Mechanical Properties of Fabrics:** The effect of 3% solution of Zycrobal on some mechanical properties of the treated yarns which are used in fabrics in comparison with the untreated one is shown in Table 4. There is no significant deterioration effect on the studied mechanical properties (e.g. the significant level of  $\alpha=0.05$ , about Table 4) [5].

**The Effect of Zycrobal on Wrinkle Resistance:** Figure 9 indicates that Zycrobal antibacterial material does not have an effect on the wrinkle property of the cotton product; however, cotton/polyester fabrics show that the wrinkle recovery angle is in the same direction of warp and after being completed by Zycrobal this angle is decreased. nonetheless, the level of this decrease in the same direction of weft is less. According to the structure of cotton/polyester fabric (polyester warp thread and cotton weft thread), it was found out that effectiveness of this material on polyester goods is higher and the wrinkle property of polyester is higher than that of the cotton goods. Generally, this material results in a small increase of wrinkle property of fabric.

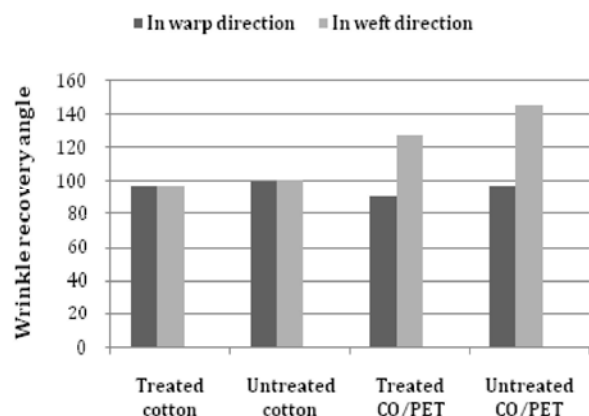


Fig. 9: Wrinkle recovery angle (WRA) of treated and untreated cotton and polyester fabrics

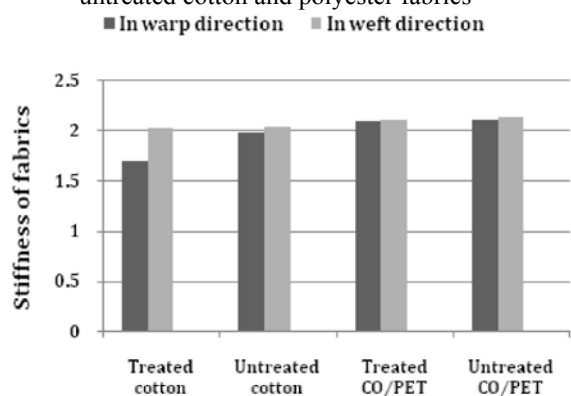


Fig. 10: Stiffness of treated and untreated cotton and polyester fabric samples

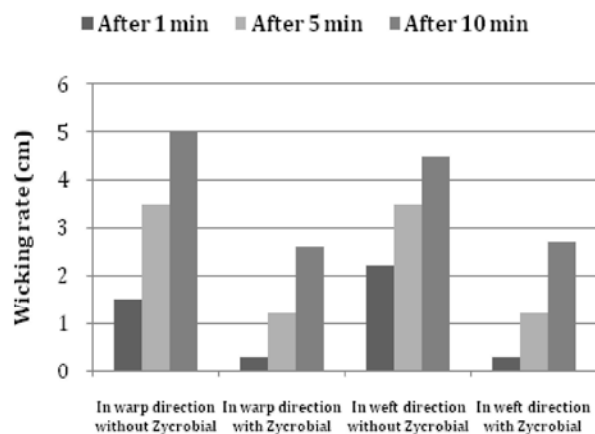


Fig. 11: Wicking rates of treated and untreated cotton fabrics

**The Effect of Zycrobial on Stiffness of Fabrics:** According to figure 10 it is indicated that Zycrobial antibacterial material does not have any effects on stiffness of the fabrics.

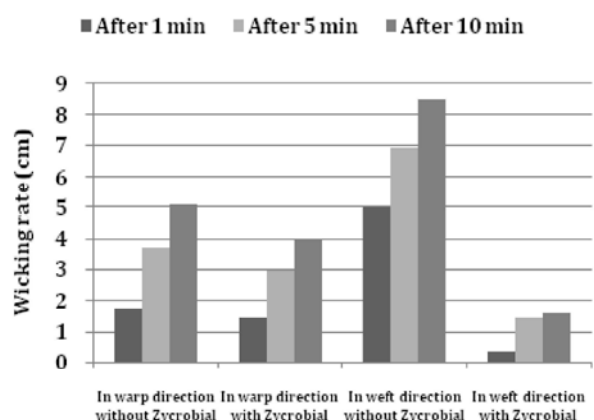


Fig. 12: Wicking rates of treated and untreated CO/PET fabrics

**The Results of Vertical Wicking Test:** According to figures 11 and 12, it is observed that when specimens were treated with Zycrobial, their wicking rate was decreased. However, this level of decrease in CO/PET fabrics (especially in warp direction) is much higher than in cotton fabrics and in fact this substance adds a hydrophobia property to the treated product.

## CONCLUSIONS

In this study, the dyed cotton and cotton/polyester blend fabrics were treated by Zycrobial as an antimicrobial agent in various finishing conditions and the dyed and treated fabrics were challenged with bacteria cultures. Enjoying an appropriate antibacterial effect, being less harmful to humans, easy to use and compatible with other agent materials are the main reasons for selection of Zycrobial as an antiseptic in this study. All the treated fabrics exhibited antimicrobial efficacy against *E.coli* and *S. aureus*. A comparison of antibacterial effects of Zycrobial on fabrics, which are dyed with different dyes, demonstrated the highest antibacterial effect appeared on those fabrics dyed with a direct dye. This is due to the large size of this molecule compared to other dyes and existence of numerous sites with negative charges that could create an affinity on Zycrobial and the fiber, whereas reactive dyes have the least effective antibacterial property due to their small structure and resistance to establishing a link with Zycrobial. Plasma finishing has a positive effect on the antibacterial activity of Zycrobial and improves durability of the antibacterial effect in comparison with domestic washing procedures. The washing durability of the dyed and treated fabrics was low, possibly caused by a loss of dyes and Zycrobial

on the fiber surface during washing. The measurement of K/S values of same fabrics further confirmed that washing might cause dye loss. Zycrobal finishing on the fabric doesn't have incompatible effects on the mechanical properties and creates a soft surface, increasing the hydrophobic properties especially in polyester fabrics while causing no changes on the shade of the colors of the dyed fabrics.

### ACKNOWLEDGEMENTS

The Authors thanks manager of colors and pigments lab and microbiological department from Tarbiyat Modares University of Tehran. The Authors are grateful for financial support given by the Zydex Co. in Mashad. Iran.

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