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INSTITUTE FOR TEXTILES AND LEATHER

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**TEXTILE RESEARCH – ACTIVE FACTOR
FOR INCREASING PERFORMANCE
AND COMPETITIVENESS**

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**THE NATIONAL RESEARCH & DEVELOPMENT INSTITUTE FOR TEXTILES AND LEATHER
ROMANIA**

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ANTIBACTERIAL EFFICACY TESTING OF SONOCHEMICALLY COATED TEXTILE FABRICS

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Keywords: sonochemical, coating, ZnO, ISO 20743, MRSA, *Acinetobacter*

Abstract: *The results presented here are from work being carried out on EU Framework 7 funded project (SONO). The aim of this project is to develop and trial a pilot line sonochemical coating system for the production of antimicrobial textiles. The technology is based on a laboratory scale sonochemical process that was developed at Bar-Ilan University (BIU). The coating is a one step process in which ultrasound causes both the formation of antimicrobial ZnO nanoparticles and actively impregnates these nanoparticles into the textile fibres.*

*As part of the project, the performance of the sonochemically produced antibacterial coating on various different fabric types is being investigated. Here we report on a comparison of ZnO coated on a plain cotton fabric and a polyester/cotton mixed fabric (65/35% mix). The antibacterial efficacy of the coated fabrics was quantitatively assessed using the absorption method from BS EN ISO 20743:2007. Six different bacteria were used for the tests: *Staphylococcus aureus*, Methicillin-resistant *Staphylococcus aureus* (MRSA), *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Acinetobacter baumannii*, all of which are commonly associated with hospital acquired infections. Antibacterial activity was demonstrated against each of the test bacteria with very high levels of activity for the ZnO coated mixed fabric. The ZnO coated mixed fabric also retained a good level of antibacterial activity following 10 cycles of washing at 92°C.*

1. INTRODUCTION

Hospital-acquired infections are thought to affect as many as 1 in 10 patients visiting European hospitals¹. These infections place a huge financial burden on healthcare systems and are responsible for many millions of deaths each year. Antibacterial fabrics for medical textiles, such as workers' uniforms, bedding and dressings, may provide a useful weapon in the on-going fight against these infections. Antibacterial fabrics may also be of benefit in other environments where the spread of bacteria can cause problems, for example in facilities handling food production or dealing with livestock.

A wide variety of antibacterial compounds have been coated onto textiles in order to introduce antibacterial properties². Amongst these metal oxide nanoparticles such as ZnO, CuO and TiO₂ have been extensively studied^{3,4,5}. ZnO has been shown to display antibacterial activity through the generation of reactive oxygen species⁶. These highly reactive chemical species exert their antibacterial effect by reacting with, and damaging, essential bacterial components such as membrane lipids and proteins⁷. ZnO is however

considered safe and is used in a wide range of topical skin formulations. There have been some concerns over the use of ZnO nanoparticles but research indicates that this too is non toxic⁸.

Ultrasonic irradiation has been shown to be an effective method for the production of metal oxide nanoparticles in solution⁹. Ultrasonic irradiation has also been shown to be effective for the deposition of nanoparticles onto various substrates, including textiles^{10,11}. Under suitable conditions, the introduction of power ultrasound (20 to 100 kHz) into a solution results in the formation of acoustic cavitation bubbles. The very rapid collapse of these unstable bubbles results in the localised generation of very high temperatures and pressures¹². When cavitation bubbles collapse close to a solid powerful miniature microjets are formed which scour the surface¹³. It is these microjets that provide the surface cleaning action in ultrasonic cleaning baths. These microjets can also propel suspended particles onto surfaces at a high enough velocity to cause binding¹⁴.

The results presented here are from an EU Framework 7 funded project (SONO). The aim of this project is to develop and trial a pilot line sonochemical coating system for the production of medical antimicrobial textiles. The project is a collaboration between 17 partners from 10 different European countries. The partners involved range from fabric manufacturers to medical end users. Further details can be found on the project website at: www.fp7-sono.eu.

The technology under development is based on a lab scale sonochemical process that was developed at Bar-Ilan University (BIU). It is a one step process in which ultrasound causes both the formation of antimicrobial ZnO nanoparticles and actively impregnates these nanoparticles into textile fibres¹⁵. As part of the project, the performance of the sonochemically produced antibacterial coating on various different fabric types is being investigated. Here we report on a comparison of ZnO coated on both a plain cotton fabric and a polyester/cotton mixed fabric (65/35% mix).

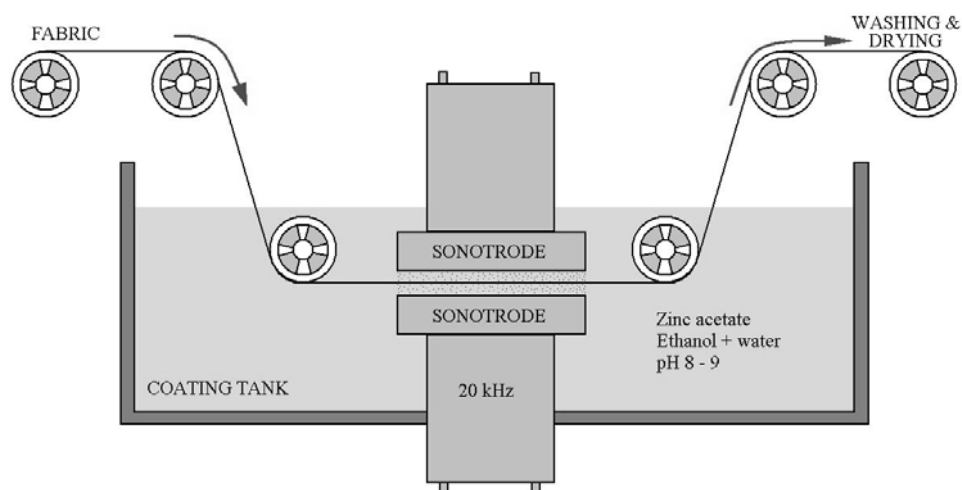


Figure 1. Schematic of sonochemical coating system for the production of antibacterial fabrics

2. MATERIALS AND METHODS

2.1 Fabric coating

The sonochemical coating of the fabrics was carried out at BIU according to their previously published procedure¹⁵. A schematic of the sonochemical coating system used is shown in Figure 1. In this system 100 mm wide strips of fabric were fed on a motorized roller system between the faces of two ultrasonic vibrating plates (21 kHz sonotrodes). Both the fabric and the sonotrodes were submerged in a solution containing the precursors for the sonochemical production of ZnO nanoparticles. This solution contained between 0.01 and 0.05 M zinc acetate dihydrate (Aldrich) dissolved in a 9:1 mixture of ethanol and water.

For the coating procedure the solution was heated to approximately 50°C and the pH was adjusted to between 8 and 9. The fabric was then fed at a constant rate through the solution and between the vibrating plates. After coating, the fabrics were washed thoroughly with clean water and ethanol and then dried. The ZnO content of the fabrics was determined by ICP following complete dissolution of the ZnO in 0.5 M nitric acid. Scanning electron microscopy was used to check for the presence of ZnO nanoparticles 10 - 50 nm in size.

2.2 Fabric types

The coating and chemical/physical characterisation of the fabrics was carried out at BIU and is not reported on here. The antibacterial efficacy of ZnO coating was investigated on 2 types of fabric:

- Cotton - 145 g/m², 27 threads per cm (warp) and 22 threads per cm (weft). Coated with 1.1 % w/w ZnO.
- Polyester (PE) cotton 65 % / 35 % blend - 210 g/m², 48 threads per cm (warp) and 23 threads per cm (weft). Coated with 0.6 % w/w ZnO.

2.3 Antibacterial efficacy testing

The antibacterial performance of the textiles was measured using the absorption method from BS EN ISO 20743:2007¹⁶. Samples of each ZnO coated fabric (test fabrics) and an uncoated fabric (control) were cut into pieces weighing 0.40 g ± 0.05 g (nominally 50 x 50 mm squares). Prior to testing these samples were sterilised in covered glass universals by autoclaving them for 15 minutes at 121°C and 103 kPa.

The bacterial species and strains used are listed in Table 1. The suspensions of bacteria used for inoculating the fabrics were prepared as follows. Overnight cultures of bacteria were grown in nutrient broth (NB, Oxoid) at 37°C and 110 rpm. Following this incubation, a 0.4 ml aliquot of the overnight culture was transferred to 20 ml of fresh nutrient broth and incubated for 3 hours at 37°C and 110 rpm. The 3 hour culture was then serially diluted 3 fold in dilute nutrient broth (1 in 20 dilution in water) and the concentration of bacteria in the suspension was adjusted to be between 1 x 10⁵ and 3 x 10⁵ colony forming units per ml (CFU/ml).

For each bacterial strain, 6 pieces of the control fabric and 6 pieces of the test fabric were inoculated with 0.2 ml of the dilute bacterial suspension. The 0.2 ml aliquot of suspension was slowly added drop wise to each fabric piece in order to allow it to be fully absorbed by the fabric pieces. Following the inoculation step, 3 of the control samples and 3 of the test samples were placed in an incubator at 37°C in capped vials. The remaining 3 control and 3 test samples were immediately mixed with 20 ml of neutralising medium (SCDLP). The resulting suspensions of bacteria were serially diluted in NB. 1 ml of each

dilution was mixed with 17 ml of molten plate count agar (PCA, Oxoid) and allowed to set in a sterile Petri dish. All plating was carried out in duplicate. These agar plates were then incubated for 24 ± 4 hours at 37°C . After this incubation the number of colonies on the plates was counted in order to calculate the inoculum cell density (CFU/ml). The remaining 3 control and 3 test pieces were incubated with the absorbed bacterial suspensions for between 18 and 24 hours at 37°C . After this incubation the fabrics were washed out with SCDLP and plated out as described above. The number of colonies on these plates was used to calculate the growth values on the control and test fabrics.

The antibacterial efficiency value (A) was calculated using the following formula:

$$A = F - G \quad (1)$$

where F = growth value on the control fabric sample (\log_{10} CFU/ml post incubation - \log_{10} CFU/ml prior to incubation). G = growth value on the treated fabric samples.

<i>Bacteria</i>	<i>Gram stain</i>	<i>Strain Number</i>
<i>Staphylococcus aureus</i>	Gram + ve	NCTC 6571
Methicillin-resistant <i>Staphylococcus aureus</i> (MRSA)	Gram + ve	NCTC 10442
<i>Acinetobacter baumannii</i>	Gram - ve	NCTC 10303
<i>Escherichia coli</i>	Gram - ve	NCTC 10537
<i>Klebsiella pneumoniae</i>	Gram - ve	ATCC 4352
<i>Pseudomonas aeruginosa</i>	Gram - ve	ATCC 15442

Table 1. List of bacteria used for the antibacterial tests

2.4 Wash tests

In order to assess the wash durability of the antibacterial coating, subsamples of the fabrics were washed for 10 cycles at 92°C (15 minute wash time per cycle). The washing procedure used was according to the guidelines laid out in BS EN ISO 6330:2001¹⁷. The antibacterial activity of the washed samples was determined using the procedure described in section 2.3.

3. RESULTS

3.1 ZnO coated cotton

The results of the antibacterial testing carried out on the ZnO coated cotton are shown in Figure 2. Some degree of activity was observed in all cases though there was some variation in the level of activity against different species of bacteria. There was a greater than 3 log reduction (99.9%) in the growth of *S. aureus*, MRSA, *K. pneumoniae* and *E. coli* with the ZnO coated cotton compared to the uncoated control. Whilst for *P. aeruginosa* and *A. baumannii* there was only just over 1 log reduction.

In order to investigate the wash durability of the antibacterial coating samples of coated fabric were washed for 10 cycles at 92°C . The results of the antibacterial testing carried out on the washed fabrics are shown in Figure 3. In each case there was a reduction in the level of antibacterial activity following the wash procedure. The greatest level of reduction in activity was observed for *E. coli*, with less than a single log reduction in cell numbers for the washed fabric compared to the pre wash activity of greater than a 5 log reduction. For the other bacteria tested the washing typically resulted in a reduction in the level of the activity of between 1 and 2 log compared to the unwashed fabrics.

3.2 ZnO coated polyester cotton

The results of the antibacterial testing carried out on the ZnO coated polyester cotton mix fabric are also shown in Figure 2. A high level of antibacterial activity was observed in all cases with levels of reduction of greater than 5 log throughout. Following the overnight incubation stage no live bacteria remained on the coated fabric samples.

As shown in Figure 3, washing of the mixed fabric again resulted in a decrease in the level of antibacterial activity. For *S. aureus*, MRSA and *E. coli* the antibacterial activity levels post washing remained above 3 log. In the particular case of *P. aeruginosa* there was much greater reduction in the activity with levels post washing reduced to just over 1 log.

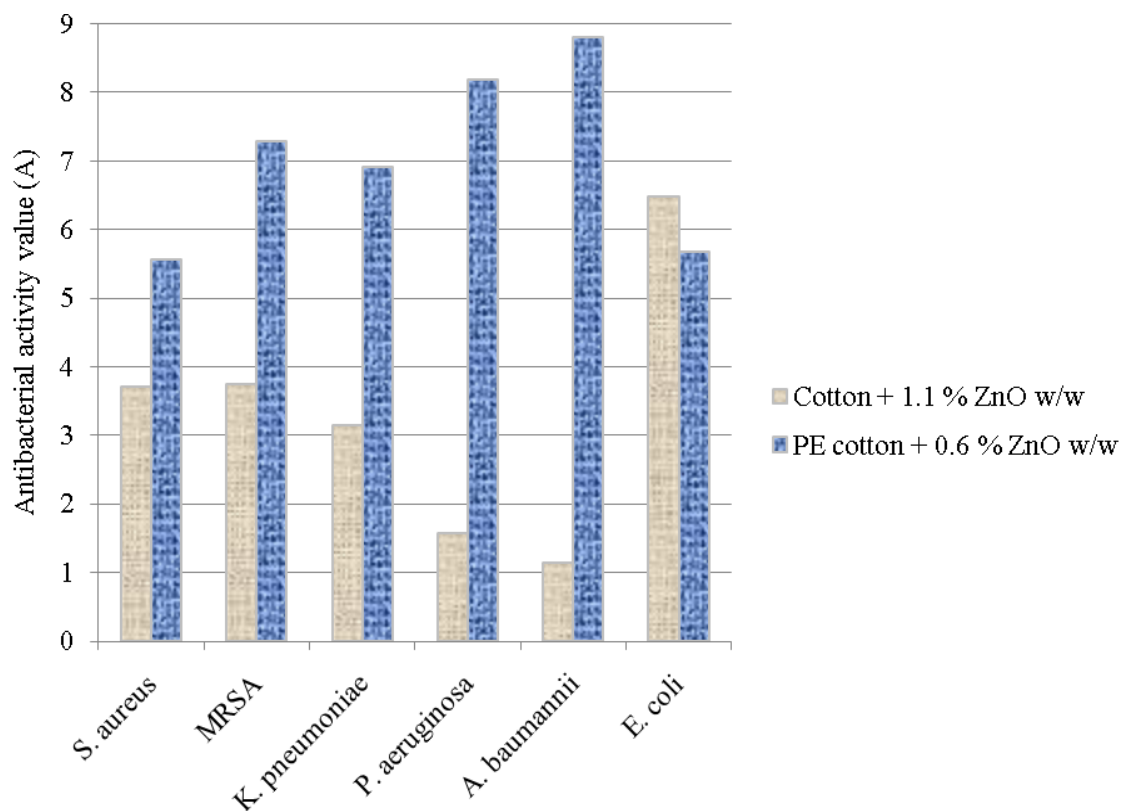


Figure 2. Antibacterial activity values for fabrics sonochemically coated with ZnO nanoparticles

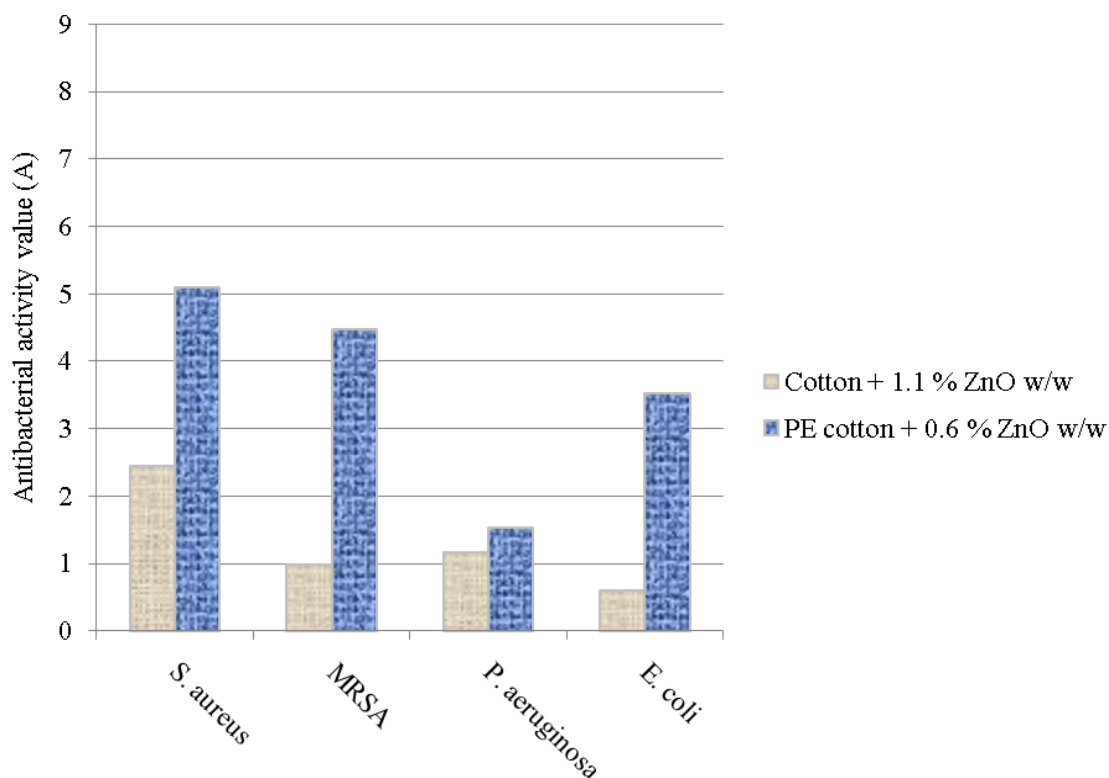


Figure 3. Post washing antibacterial activity values for fabrics sonochemically coated with ZnO nanoparticles (10 wash cycles at 92°C)

4. DISCUSSION

Textiles sonochemically coated with ZnO have been shown previously to possess antibacterial activity against *S. aureus* and *E. coli*¹⁰. Here it is shown that this antibacterial activity extends to a range of other bacteria including examples of organisms that cause hospital acquired infections. Both fabric types displayed antibacterial activity against all of the test bacteria with very high levels of bacterial reduction ($> \log 5$) for the ZnO coated PE/cotton mix fabric.

In the case of the ZnO coated cotton, there were quite large differences in the levels of antibacterial effectiveness against the different bacterial species. Out of the 6 bacteria used, *P. aeruginosa* and *A. baumannii* appeared to be the least susceptible to the antibacterial effect of the ZnO on cotton. Both these organisms can cause infections which are hard to treat, and display intrinsic resistance to a number of antimicrobial agents¹⁸. Interestingly both these bacteria were however shown to be highly susceptible to the ZnO nanoparticles on the PE/cotton mixed fabric. It is not clear exactly why this could be as the coating level on the mixed fabric was actually lower than on the cotton (0.6 % and 1.1 % w/w respectively). The variation in effectiveness of the ZnO on the two substrates may result from a difference in the way the nanoparticles are presented on the surface of the fibres. On-going scanning electron microscopy studies may provide information to help explain these findings.

The coating of the fabrics is thought to be via physical bonding rather than chemical bonding¹⁹. The sonochemical production of the coated fabric involves two processes that are the result of acoustic cavitation: the generation of the nanoparticles *in situ* and simultaneously the propulsion of the nanoparticles at high velocity onto the fabric¹⁴. The velocity of the nanoparticles on impact is sufficient to cause impregnation into the cotton

fibres and enough heat on collision with polyester fibre to produce melting. This very localised melting is enough to bond the nanoparticles onto the plastic fibres. Results from antibacterial tests carried out on washed fabric samples (10 cycles at 92°C) also suggest that the antibacterial coating is more firmly attached to the polyester cotton mix fabric than it is to the cotton fabric.

Following the washing procedure the antibacterial effectiveness of both fabrics was reduced. The reductions observed are presumably due to a loss of ZnO during washing. Again though, the antibacterial effectiveness of the mixed fabric remained higher than that of the cotton fabric. A detailed investigation into the effects of washing on the chemical and physical properties of the fabrics is currently being undertaken by the National R&D Institute for Textiles and Leather, Romania (INCDTP).

The sonochemical coating process can be used to coat fabrics with other antimicrobial nanoparticles such as CuO and MgO^{5,11,15,19}. Further tests are being carried out to determine if other coatings are more resistant to washing than ZnO.

5. CONCLUSION

The results presented here show a positive antibacterial effect associated with the sonochemical coating of the textiles with ZnO nanoparticles. This antibacterial activity has been demonstrated against 6 different types of bacteria included species that are commonly associated with hospital acquired infections. The antibacterial properties of ZnO coated mixed fabric (polyester/cotton) were particularly good, with bacterial cell numbers reduced to zero during overnight incubations.

The antibacterial effectiveness of the ZnO coating was found to be reduced following repeated washing cycles presumably through the loss of ZnO material to the washing solutions (is this under investigation). However antibacterial activity levels were not reduced to zero, and in the case of the coated ZnO mixed fabric remained high against 3 of the 4 bacteria tested.

The sonochemical coating process has the potential to be used for a range of textiles and can be used to apply a range of different nanoparticles. Compared to other coating processes the sonochemical technology has the potential to be both economically competitive and environmentally green. Production of the nanoparticles and impregnation is accomplished in a single step process, and no toxic chemicals are used.

The next stage in the SONO project will involve the assessment of the antibacterial activity of fabrics produced by pilot scale machines installed at two European fabric production companies (Klopman International, Italy and Davo Star Impex SRL, Romania).

6. ACKNOWLEDGEMENTS

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THE EVALUATION OF ANTIBACTERIAL PROPERTIES OF TEXTILES TREATED WITH TiO₂ /Ag NANOPARTICLES

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Keywords: silver, titanium oxide, textile, antibacterial, hydrophobin

Abstract: *The paper presents the results of cotton/polyester textile fabrics finished with a new generation of antimicrobial agents based on composite colloidal powders of silver - TiO₂ nanoparticles, aiding in the functionalization of textile materials used in medicine for bacterial infections' treatment. The tests revealed that the obtained materials do not change their physical/mechanical and comfort properties after applying the antibacterial treatment. The presence of nanoparticles on the textile surface was highlighted using scanning electron microscopy and SEM/EDAX analysis. Antifungal (ASTM E2149, ISO 20743:2007) and antibacterial tests (ASTM E2149) confirmed the existence of a biocidal potential, depending on the content of the nanoparticles and the tested microorganisms.*

1. INTRODUCTION

Nosocomial infections represent one of the main concerns in today's medical life being a real threat to human health. Prolonged hospitalizations, the existence of pathogen factors in hospitals, antibiotics resistance, compromised immune system and invasive procedures are a small part of the factors that contribute to the difficulty to control and eradicate the nosocomial infections [1].

Textile materials used in the medical sector (medical gowns, surgical drapes, curtains, bed linens, etc.) they all constitute an ideal environment for the growth and spreading of microorganisms between patients and medical staff. This represents the main reason for creating textile materials that could stop pathogen factors proliferation.

TiO₂/Ag composite powder has been the most used compound for obtaining textiles with antibacterial properties. The use of this composite is based on a double edged effect: the photocatalytic properties of TiO₂ and antibacterial property of silver. Scientific studies[2] demonstrated the increase of photo catalytic properties of titanium dioxide by silver doping due to the electrons transfer from TiO₂ to Ag, and the reduction of recombination electron-hole (e--h+) pairs at TiO₂ surface. [3,4].

It has been demonstrated that TiO₂ doped with silver can decompose organic compounds (phenol, sucrose), dyes and organic acids (oxalic acid, salicylic acid)[5-9], gases (H₂S, CH₃SH, N₂O), etc.[10,11]. Keleher et al. [12] obtained TiO₂/Ag nanoparticles with antibacterial activity similar to other antibiotics (tetracycline, cloramphenicol, erythromycin, neomycin). Other studies confirmed the antibacterial activity against *E. coli*, *St. aureus*, *S. cerevisiae* and pathogen fungi from *Candida* family [13].

The study presents the results of testing cotton/polyester fabrics with a new generation of antimicrobial agents based on colloidal suspensions of composite nanopowders based on TiO₂/Ag, with applications in the functionalization of textile products used in medical fields for preventing bacterial infections.

2. MATERIALS AND METHODS

2.1 Textile materials

A 56/44% cotton/polyester twill woven was used as support for hydrophobins and later, for TiO₂/Ag nanopowder deposition.

2.2 Chemical reagents

- 0.5% hydrophobins solutions: H*Protein A(HA) and H*Protein B(HB), obtained from BASF, Germany. The proteins were prepared in phosphate buffer solution, pH 6.5;
- Ag/TiO₂ solutions, characterized by the properties shown in Table 1.

Sample	Ag, %; ppm	TiO ₂ , %	Np average diameter (nm)	Suspension pH value	Zeta potential , ζ , (mV)	Aspect
1	0.0075; 75ppm	5%	10.8	8.50	-33.44	White-gray dispersions
2	0.075%; 750ppm	5%	28.7	9.02	-39.80	White-gray dispersions
3	1.5%; 1500ppm	5%	36.9	8.82	-43.67	Brown-gray dispersions

Table 1: Characteristics of TiO₂/Ag nanoparticles solutions (stabilized with PAS, the sodium salt of polyacrylic acid)

2.3 Textile materials

a) Fabric treatment with hydrophobins.

The fabric is immersed in the hydrophobins solution (material:bath ratio=1:9), and maintained at 80°C for 4h. Then, 8 grams sodium dodecylsulphates are added in the hydrophobin bath (4l) and the solution is heated to 100°C for 10 minutes. Next, the material is washed with tap water and left to dry at room temperature.

The fabrics are re-immersed in fresh hydrophobins solutions and kept at room temperature (25°C) for 24 hours.

b) Fabric treatment with hydrophobins and metal-oxide solutions.

The treatment was done by immersion of the fabrics in 50g/l metal-oxide solutions, at a material/bath ratio of 1g:30mL. The fabric is kept in this solution for an hour at room temperature with occasional stirring. The fabrics are then removed from the bath and left to dry at room temperature.

3. TESTS AND ANALYSIS

The fabrics treated with TiO₂/Ag were physically, mechanically and biologically characterized.

Physical and mechanical analyses, according to ISO standards, are focused on assessment of comfort degree: mass, thickness, water and air permeability, breaking strength, thermal and electrical conductivity. The morphology of the fabrics treated with hydrophobins/TiO₂/Ag was analyzed using scanning electron microscope (Quanta 200, FEI).

The identification of hydrophobins was done using Congo Red, Thioflavine T and Nynhidrin. Antibacterial efficiency of the treated fabrics was tested according to ASTM E2149 standard and the antifungal activity was tested against *Candida albicans* ATCC 90028 using the absorption method, standard ISO 20743:2007. Both testing standards were slightly modified.

4 RESULTS AND DISCUSSIONS

4.1 Physical and mechanical characteristics of the treated fabrics

Physical and mechanical characteristics of the fabrics treated initially with hydrophobins, and subsequently with metal-oxide solutions, are presented in Table 2 and 3.

Analysis/Values		Untreated fabric	Fabric treated with HA	Fabric treated with HA + solution:			Standard
				1HA	2HA	3HA	
Mass, g/m ²		155	164	161	159	159	SR EN 12127/2003
Thickness, mm		0.407	0.426	0.44	0.44	0.44	SR EN ISO 5084/2001
Apparent diameter (µm)	U	166	178.5	170.0	171.0	171.5	SR 13152/93
	B	190	197	199.0	201.5	201.0	
Density, nr. of fibres/10 cm	U	350	350	353	350	350	SR EN ISO 1049-2/2000
	B	280	290	288	286	290	
Air permeability, l/m ² /s; 100Pa		137	120.3	110.8	122.6	117.3	SR EN ISO 9237/1999
Water vapour permeability, %, 3h		36.8	41.09	34.6	38.5	41.07	SR 9005-1979
Surface resistivity, Ω		2.62·10 ¹¹	1.88·10 ¹⁰	2.3x10 ¹¹	1.86x10 ¹¹	2.83x10 ¹¹	SR EN1149-1/2006
Volume resistivity, Ω		6.03·10 ⁹	9.41·10 ⁷	3.0x10 ⁹	1.4x10 ⁹	8.78x10 ⁸	

Table 2: Physical-mechanical characteristics of fabrics treated with hydrophobin A (HA) and TiO₂/Ag

Analysis/Values	Untreated fabric	Fabric treated with HB	Fabric treated with HB + solution:			Standard	
			1HB	2HB	3HB		
Mass, g/m ²	155	163	163	161	159	SR EN 12127/2003	
Thickness, mm	0.407	0.426	0.44	0.43	0.44	SR EN ISO 5084/2001	
Diameter (μm)	U	166	177	171.0	170.5	176.0	SR 13152/93
	B	190	202	201.5	200.5	206.5	
Density, Nr. of fibres/10 cm	U	350	350	353	351	350	SR EN ISO 1049-2/2000
	B	280	289	288	288	285	
Air permeability, l/m ² /s; 100Pa	137	125	113	120.6	120.3	SR EN ISO 9237/1999	
Water vapour permeability, %, 3h	36.8	43.7	34.8	37.5	42.2	SR 9005-1979	
Surface resistivity, Ω	2.62·10 ¹¹	2.17·10 ¹¹ ₀	4.2x10 ¹¹	3.7x10 ¹¹	9.0x10 ¹¹	SR EN1149-1/2006	
Volume resistivity, Ω	6.03·10 ⁹	1.35·10 ⁸	7.6x10 ⁸	1.75x10 ⁹	1.3x10 ⁹		

Table 3: Physical-mechanical characteristics of fabrics treated with hydrophobin B (HB) and TiO₂/Ag

The results (Table 2 and 3) reveal a mass grow of 5.8% in case of hydrophobin A deposition, and 5.1% in case of the deposition of B hydrophobin. The deposition of hydrophobins on the fabric is demonstrated by the growth of mass, apparent diameter and constant fabric density.

Surprising is the small loss of mass (1.2-3%) after metal-oxide solution deposition, although both fiber thickness and diameter increase. The loss of mass can be associated with the removal of a small part of the deposited hydrophobins. As the concentration of the silver increases, the mass, warp density (polyester) and air permeability decrease.

Remarkable is the decreasing of air permeability to 12.28% in case of hydrophobin A and 8.75% in case of hydrophobin B. Usually, a regular polymer forms a film on the surface of the fabric, which causes the decreasing of air permeability. In the case of hydrophobins treatment, it looks like they don't form a film on the fabric, instead the fibres are wrapped with a thin layer of hydrophobins. The hypothesis is confirmed by thickness and apparent diameter growth as through scanning electron microscopy.

Water vapour permeability increases in the case of fabric deposition with hydrophobin A with 11.65% and with 18.75% in case of hydrophobin B, demonstrating an increased hydrophilic character of the treated fabric. Considering that mass growth is smaller in case of hydrophobin B, it is noticeable that hydrophilisation is higher in case of hydrophobin B, probably due to the more hydrophilic groups which attract more atmospheric water molecules compared with hydrophobin A.

It is worth mentioning the minor modification of physical and mechanical properties of the fabric, ensuring a high breathability and degree of comfort.

4.2 Morphological characterization of textile materials treated with hydrophobins

SEM images (Figures 1-6) show a massive deposition of metal-oxide particles on the surface of the fabrics.

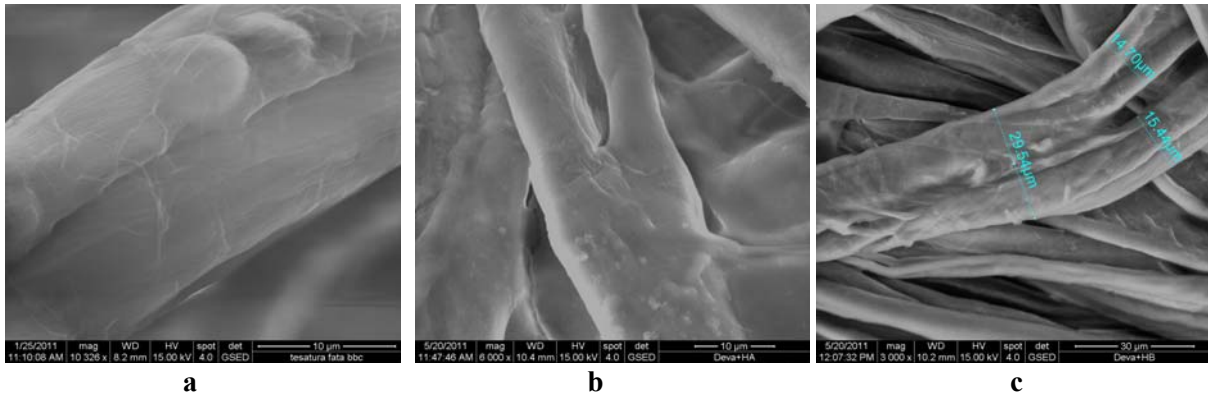


Figure 1: SEM images of cotton fibres (fabric): a-untreated; b-treated with HA; c-treated with HB

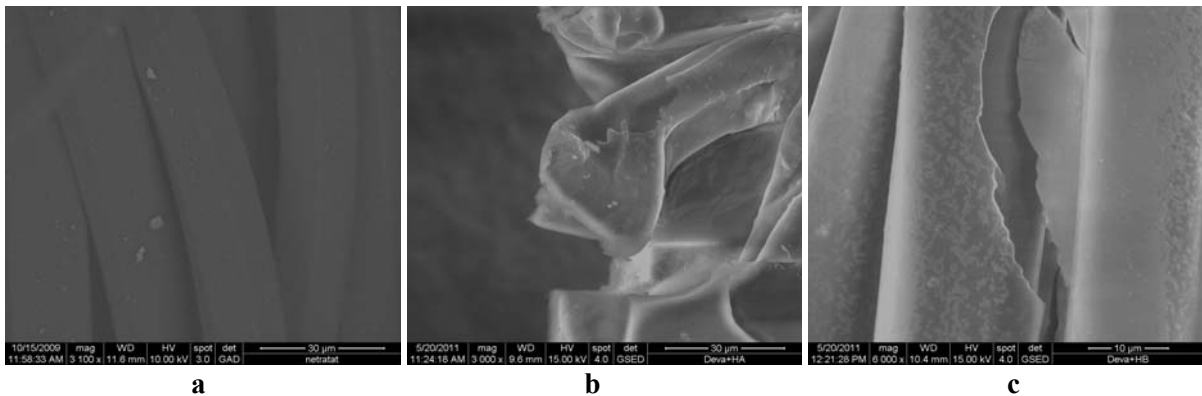


Figure 2: SEM images of polyester fibres (fabric): a-untreated; b-treated with HA; c-treated with HB

SEM images (Figure 2) show the deposition of hydrophobins on the fabric. The deposition mode and quantity depend on the type of hydrophobin and used fibres. Thereby, on cotton fibres, the deposition is irregular, formed layers being thinner than those formed on polyester fibres, where the deposition is massive, uniform in case of hydrophobin A and random in case of hydrophobin B.

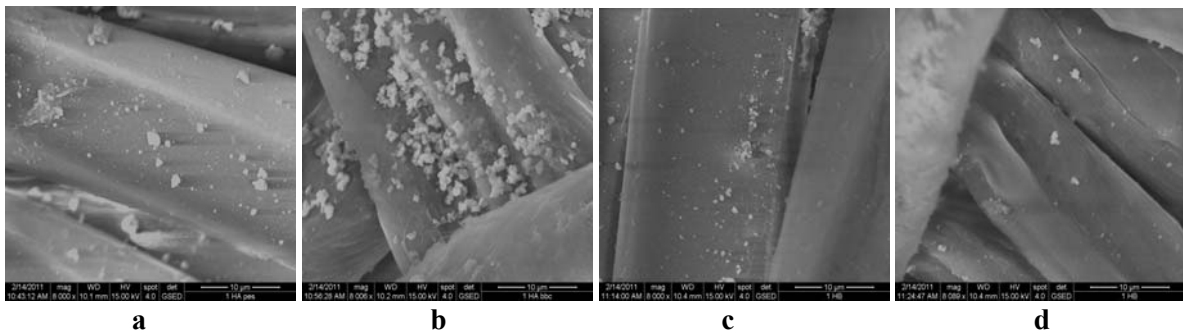


Figure 3: SEM images of cotton/polyester fiber treated with: a-HA and solution 1 (PES fibres); b-HA and solution 1 (cotton fibres); c-HB and solution 1 (PES fibres); d-HB an solution 1 (cotton fibres)

The irregular deposition of metal-oxide nanoparticles on the surface covered with thin layers of hydrophobins (Figure 3) is obvious. Apparently, on the fabric treated with HA there is a larger quantity of particles, in comparison with the one treated with HB. Also, the deposition is significant on the polyester fibres compared with cotton fibres. EDAX analysis (Figure 4) confirm the deposition of hydrophobins and TiO_2/Ag on the fabric.

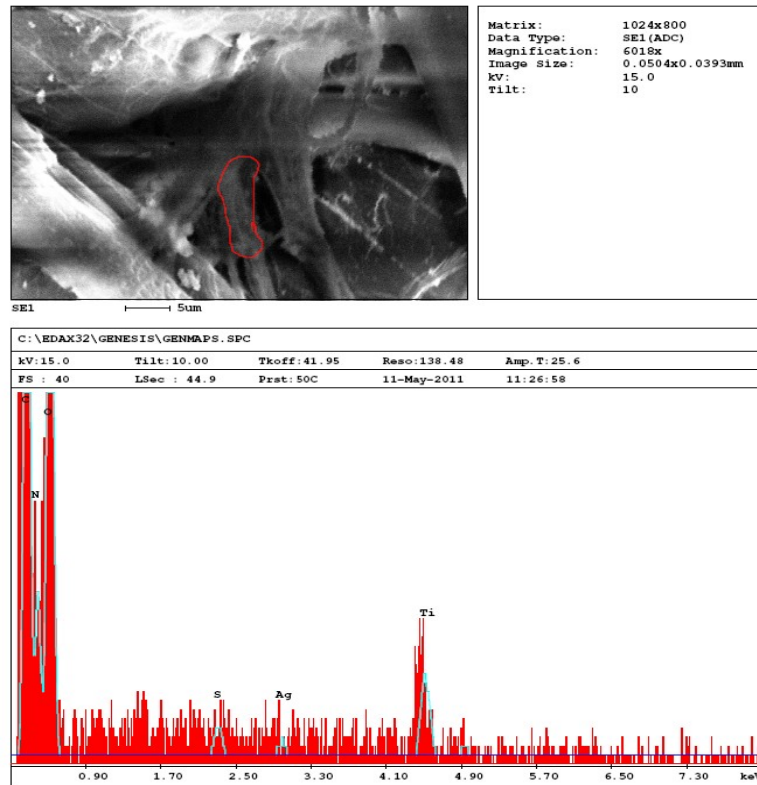


Figure 4: Energy-dispersive spectroscopy spectrum of TiO_2/Ag particles deposited on the fabric (1HA)

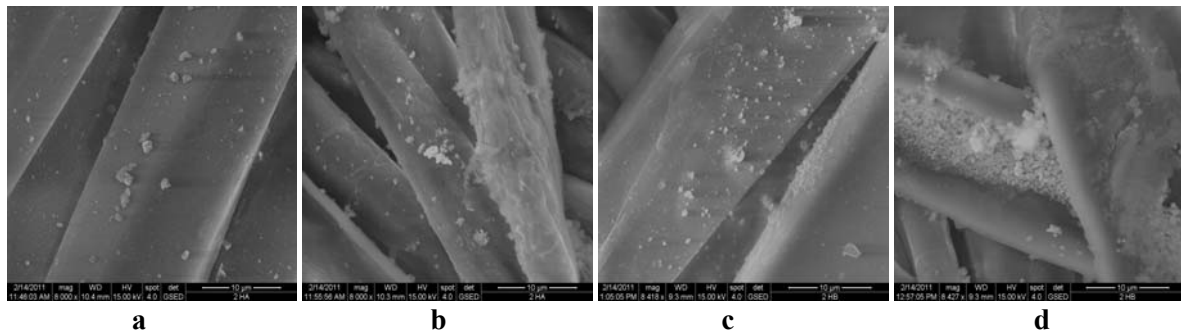


Figure 5: SEM images of cotton/polyester fabric treated with: a-HA and solution 2 (PES fibres); b-HA and solution 2 (cotton fibres); c-HB and solution 2 (PES fibres); d-HB and solution 2 (cotton fibres)

Apparently, solution 2, containing a larger quantity of silver nanoparticles, covers mostly the cotton fibres covered with HB. On the other hand, on polyester fibres, the particles have smaller size and are dispersed more uniformly.

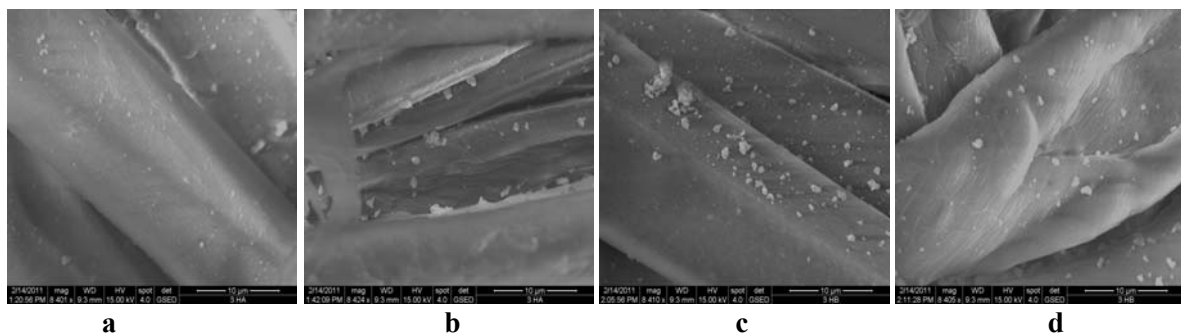


Figure 6: SEM images of cotton/polyester fabric treated with: a-HA and solution 3 (PES fibres); b-HA and solution 3 (cotton fibres); c-HB and solution 2 (PES fibres); d-HB and solution 2 (cotton fibres)

Although solution 3 has the biggest silver concentration (1500ppm), the number of deposited particles, according to SEM images (Figure 6), is slightly smaller than the one made with solution 2. It is assumed that because of the high concentration, the particles agglomerate as clusters due to Van der Waals forces, this leading to a poor affinity of the clusters for the fabric, thus remaining in the solution.

4.3 Hydrophobins identification

Hydrophobins are proteins, with small molecular weight (7-15 kDa), which can auto-assemble depending on the substrate and reaction parameters (solvents, pH, temperature, etc.). The main problem is how these hydrophobin fibrillar aggregates can be identified in the same mode as amyloid fibrils developed in neuro-degenerative diseases like Alzheimer.

Different studies [14,15] revealed that after assembling, the hydrophobins can bind to certain dyes like Thioflavin T (ThT) and Congo Red (CR) and can modify their spectroscopic structure similar to amyloid fibrils. Based on these facts, the hydrophobins were identified by optical microscopy after staining with ThT, RC and Nynhidrin.

For this purpose, a few drops of hydrophobins A and B (0.05%) in phosphate buffer (pH=6.5) were deposited on glass slides, which were afterwards stained with ThT 10.0 μ M and CR 0.0356% solutions. The slides were kept at room temperature ($\sim 20^{\circ}\text{C}$) for 24 hours. After that, the slides were mounted and viewed using an inversed optical microscope, Axiovert 40 CFL, from Carl Zeiss, Germany. The images are shown in Table 4.

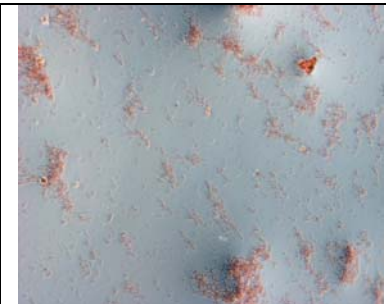
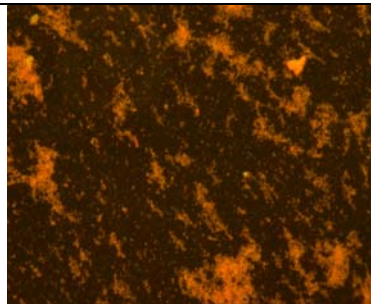
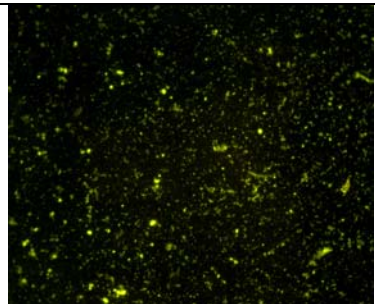
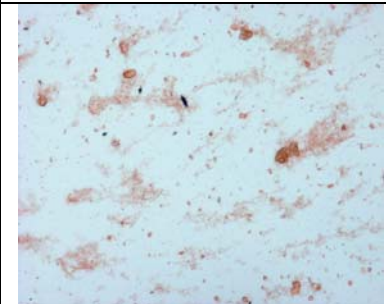
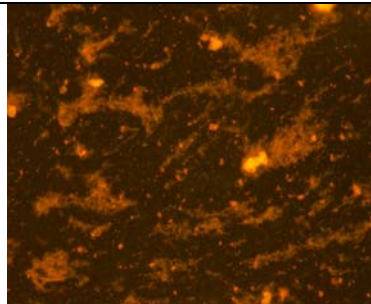
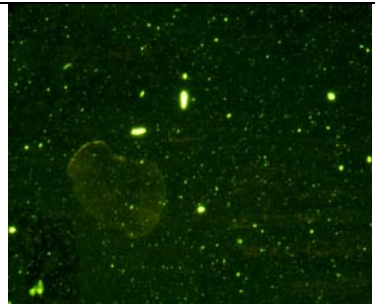
		
HA – Congo Red staining (phase contrast), 10x	HA – Congo Red staining (epifluorescence), 10x	HA – Thioflavin T staining (epifluorescence), 10x
		
HB – Congo Red staining (brightfield), 10x	HB – Congo Red staining (epifluorescence), 10x	HB – Thioflavin T staining (epifluorescence), 10x

Table 4: Microscopic images of hydrophobins stained with Congo Red and Thioflavin T

From the above images, it is visible that the hydrophobins form clusters, irregularly distributed on the glass slide. Congo Red stains both types of hydrophobins in a intense red colour.

The interaction of amyloid fibrils with Thioflavin T takes place across the fiber axis in the “sheets” formed by the side chains of amino acids residues, when β sheets forming takes place. This interaction with the side chains that prevents the free rotation between the two

cycles of ThT leads to increased fluorescence and allows for hydrophobins identification. Hydrophobins stained with Congo Red were kept at room temperature for a week, and then mounted on a carbon conductive tape for analysis by scanning electron microscope (SEM) and optical microscopy (epifluorescence). The images are shown in Table 5.

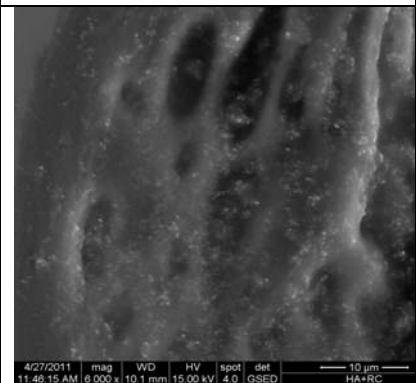
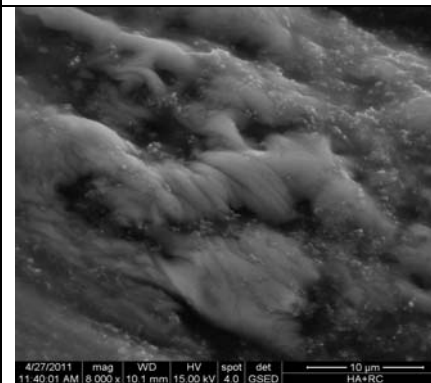
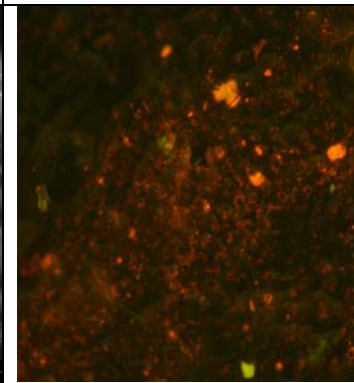
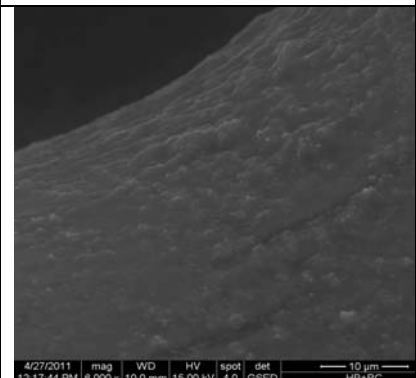
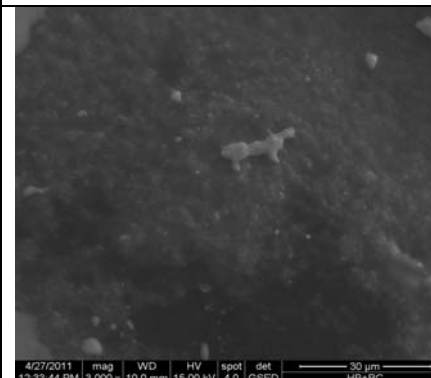
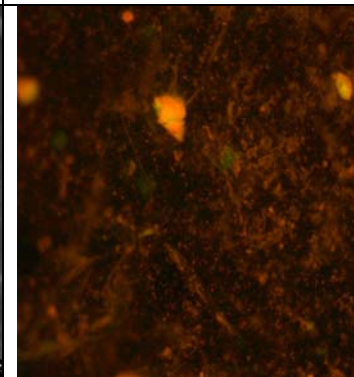
SEM image: HA stained with CR and mounted on carbon conductive tape; x6000	SEM image: HA stained with CR and mounted on carbon conductive tape; x8000	HA – Optical microscopy image, epifluorescence; x10
		
SEM image: HB stained with CR and mounted on carbon conductive tape; x6000	SEM image: HA stained with CR and mounted on carbon conductive tape; x8000	HB – Optical microscopy image, epifluorescence; x10
		

Table 5: Microscopic images of hydrophobins stained with Congo Red and mounted on carbon conductive tape

SEM images (Table 5) show that, in time, hydrophobin A auto-assembles itself in a fibrillar form, almost parallel, randomly interconnected. Apparently, these fibrils have an α -helicoidal structure. Hydrophobin B doesn't present the same fibrillar form, but forms a thick layer, with multiple clustering and a β structure.

Congo Red stain specifically reacts with amyloid fibrils, preventing their formation and staining the existing ones in red (in visible light) or producing a green birefringence (in polarized light) because of the insertion between protein sheets. Congo Red dye allows for the identification and quantification of fibrils forming, being a potential alternative to the evaluation of amyloid fibrils using fluorescence analysis with ThT.

It is not possible to identify the deposition of hydrophobins on textile materials using CR and ThT because of their affinity for cellulosic fibres. Because of this, the presence of hydrophobins on textile materials was shown with Nynhidrin staining, a reagent used for amino-acids identification. The following method was used: the materials were sampled as follows: untreated fabric, fabrics treated with HA, HB, 1HA, 1HB, 2HA, 2HB, 3HA, 3HB.

The fabrics were placed in Petri dishes, and 0.3 mL Nynhidrin 0.4% was poured over each sample. The fabrics were kept for 4 days at room temperature (~22°C). The images are shown in Table 6.

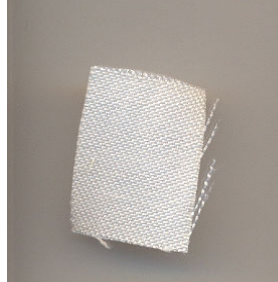
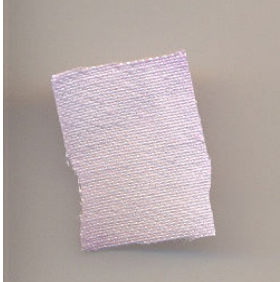




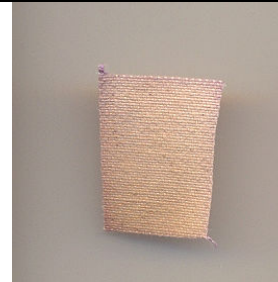
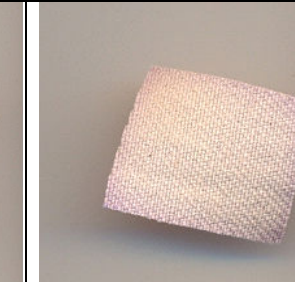
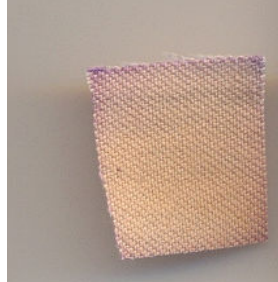



			
Untreated material	Treated with HA	Treated with HB	Nynhidrin (0.4%) + HA and HB 13 minutes; ~ 50°C
			
Treated with 1HA	Treated with 1HB	Treated with 2HA	Treated with 2HB
			
Treated with 3HA	Treated with 3HB	Optical microscopy image of fabric treated with HA and stained with Nynhidrin 0.35%	Optical microscopy image of fabric treated with HB and stained with Nynhidrin 0.35%

Table 6: Hydrophobins identification through Nynhidrin staining

After the 4 days period, all fabrics are stained, except for the untreated one. The fabrics treated with HA, HB, 1HA and 1HB developed a purple stain after 48 hours, and the ones treated with 2HA, 2HB, 3HA, 3HB developed discreet purple stains after 72 hours. The more vivid staining, correlated with the smaller time for colour developing, for the fabrics treated with 1HA compared with the ones treated with 2HA and 3HA is determined by the smaller quantity of metal-oxide particles found on the fabric surface.

Although at first the fabric treated with HA is more coloured compared with the one treated with HB, after TiO₂/Ag treatment, the colour intensity of fabrics treated with HA and TiO₂/Ag decreases as the silver concentration increases. The less vivid colouring demonstrates that hydrophobin A retains a greater quantity of particles compared to hydrophobin B.

4.4 Biological testing

Antimicrobial efficiency of the fabrics was tested against both bacterial and fungal species. Two slightly modified methods were used:

- ASTM E2149 – This test method is designed to evaluate the antimicrobial activity of non-leaching, antimicrobial-treated specimens under dynamic contact conditions. Surface antimicrobial activity is determined by comparing results from the test sample to simultaneously run controls.
- ISO 20743:2007, absorption method – A quantitative test method to determine the antibacterial activity of antibacterial finished textile products. The fungal suspension is inoculated directly onto the fabric samples. The treated fabrics were tested in parallel with the untreated material.

For antimicrobial effect quantification, colony plate count method was used to assess the reduction rate.

4.4.1 Antibacterial testing

The antibacterial efficiency of the fabrics treated with hydrophobins and TiO₂/Ag was tested against *Pseudomonas aeruginosa* (ATCC 9027), *Staphylococcus aureus* (ATCC 6538) and *Escherichia coli* (ATCC 8739). The results are presented in Table 7 and 8.

Sample	Antibacterial efficiency		
	<i>Pseudomonas aeruginosa</i> (ATCC 9027)	<i>Staphylococcus aureus</i> (ATCC 6538)	<i>Escherichia coli</i> (ATCC 8739)
1HA	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.1 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0UFC/mL R=100%
2HA	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.2 x10 ³ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0UFC/mL R=100%
3HA	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.13 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.30 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%

Table 7: Antibacterial efficiency of fabrics treated with hydrophobin A and TiO₂/Ag (ASTM E2149). Test carried out by UMF-Iasi.

Sample	Antibacterial efficiency		
	<i>Pseudomonas aeruginosa</i> (ATCC 9027)	<i>Staphylococcus aureus</i> (ATCC 6538)	<i>Escherichia coli</i> (ATCC 8739)
1HB	T ₀ =0.3 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.19 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.2 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%
2HB	T ₀ =0.3 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.1 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.3 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%
3HB	T ₀ =0.3 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.1 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%	T ₀ =0.3 x10 ⁵ CFU/mL T ₂₄ =0 CFU/mL R=100%

Table 8: Antibacterial efficiency of fabrics treated with hydrophobin B and TiO₂/Ag (ASTM E2149). Test carried out by UMF-Iasi.

Note: R = rate of reduction; reduction is considered excellent if $R > 99.9\%$, good if between $99 - 99.9\%$ and weak if between $0 - 99\%$.

The results show 100% inhibition of all the tested bacterial strains.

4.4.2 Antifungal testing

The antifungal efficiency was tested against *Candida albicans* (ATCC 90028), fresh culture. The results are presented in Table 9-10 and Figure 7.

Sample	Antibacterial efficiency	Sample	Antibacterial efficiency
1HA	$T_0=0.2 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%	1HB	$T_0=0.3 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%
2HA	$T_0=0.3 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%	2HB	$T_0=0.3 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%
3HA	$T_0=0.20 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%	3HB	$T_0=0.20 \times 10^5$ CFU/mL $T_{24}=0$ CFU/mL R=100%

Table 9: Antifungal efficiency of fabrics treated with hydrophobins and TiO_2/Ag (ASTM E2149). Test carried out by UMF-Iasi.





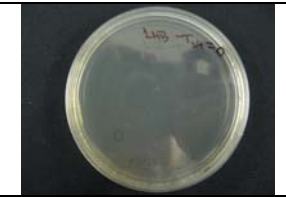

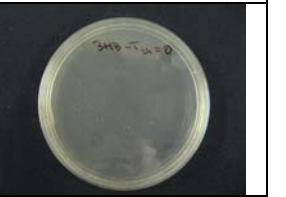
	Untreated fabric $T_0=1 \times 10^3$ CFU/mL $T_{24}=1 \times 10^4$ CFU/mL	
1HA - T_{24}	2HA - T_{24}	3HA - T_{24}
		
R= 88%	R= 97%	R= 100%
1HB - T_{24}	2HB - T_{24}	3HB - T_{24}
		
R= 100%	R= 100%	R= 100%

Table 10: Antifungal efficiency of fabrics treated with hydrophobins and TiO_2/Ag (ISO 20743:2007). Test carried out by I.N.C.D.T.P. Bucuresti.

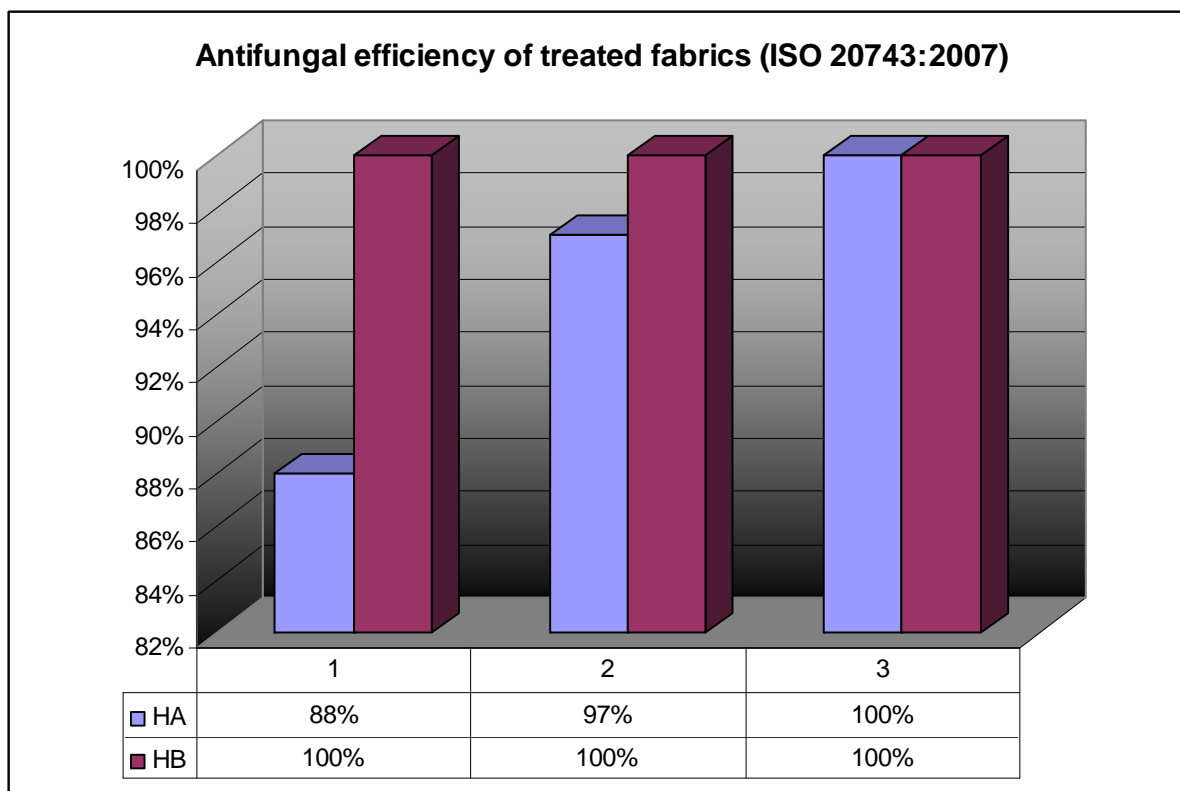


Figure 7: Comparison of antifungal efficiency of fabrics treated with hydrophobins and TiO₂/Ag, against *C. albicans* according to ISO 20743:2007

The absorption method revealed that the antifungal efficiency of the fabric treated with hydrophobin A and TiO₂/Ag improves with increasing the silver concentration. Therefore, at a 75ppm silver concentration, the rate of reduction is 88%, at 750ppm, 97% and at 1500ppm, 100%. This is not the case for the fabric treated with hydrophobin B and TiO₂/Ag, as the reduction rate for all three treatments is 100%. The untreated fabric allowed the yeast cell to multiply during the 24h incubation time.

4.5 Assessment of yeast-fabric interaction using Scanning Electron Microscopy

The assessment of activity of the treated fabrics was carried out with the help of SEM analysis. The untreated and treated fabrics were inoculated with a fungal suspension of *Candida albicans*, fresh culture, grown in Sabouraud - dextrose broth, with a concentration of 1x10⁷ CFU/mL. The inoculated samples were incubated for 3 days at 37°C. After the incubation period, the samples were mounted on stabs, and visualized using scanning electron microscopy.

The interaction between yeast cells and TiO₂/Ag nanoparticles led to loss of cellular volume and cell wall collapsing as seen in Figure 8.

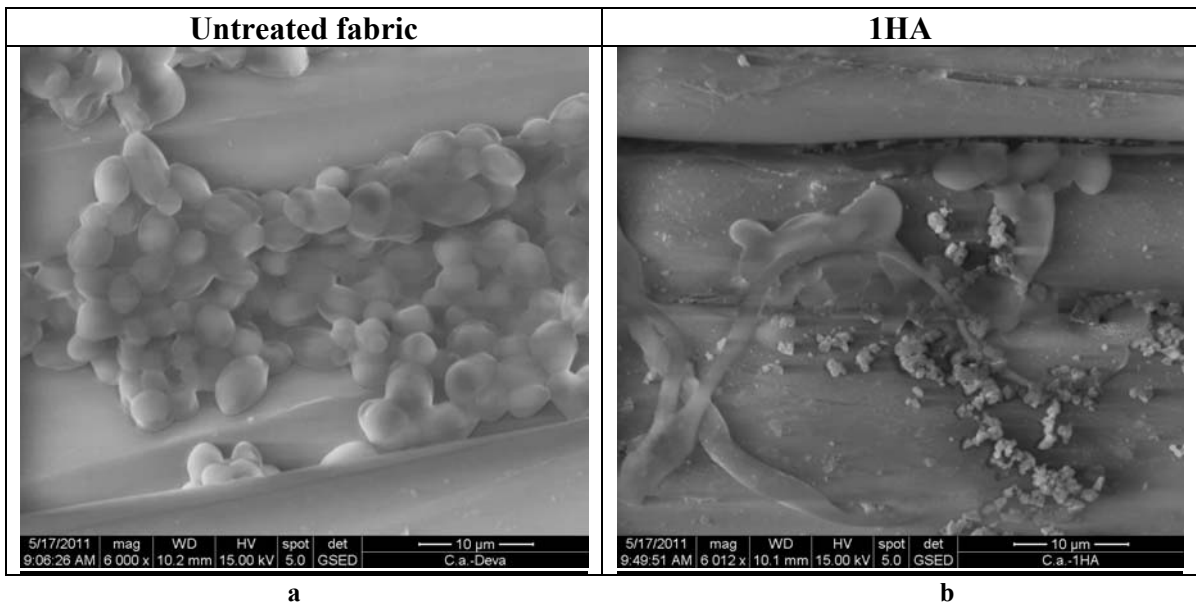


Figure 8: Effect of fabric treatment on yeast cells: a. untreated fabric; b. fabric treated with 1HA

It is important to mention that the inoculation was done from the stock solution, so the fabrics were soaked with nutritive media. However, the untreated fabric allowed the cells to multiply over the 3 days incubation period, while the treated fabrics inhibited cell proliferation, as seen in Figure 9.

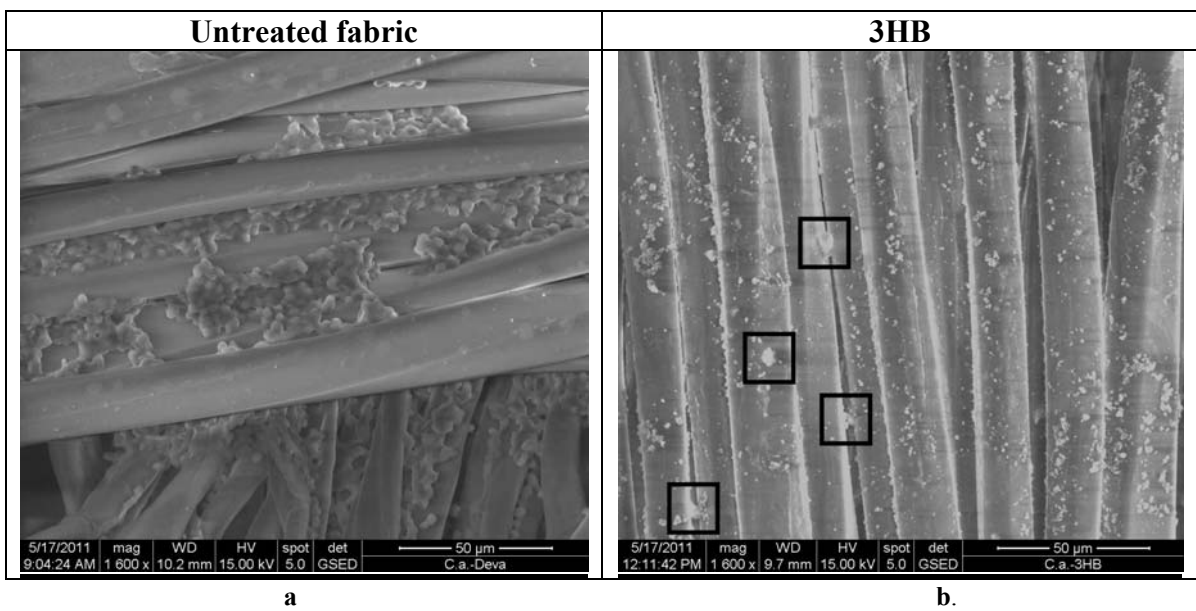


Figure 9: Yeast cells proliferation inhibition: a. untreated fabric; b. fabric treated with 3HB

SEM images reveal that nanoparticles bind to the structure of yeast cells, altering their structural morphology, as seen in Figure 10.

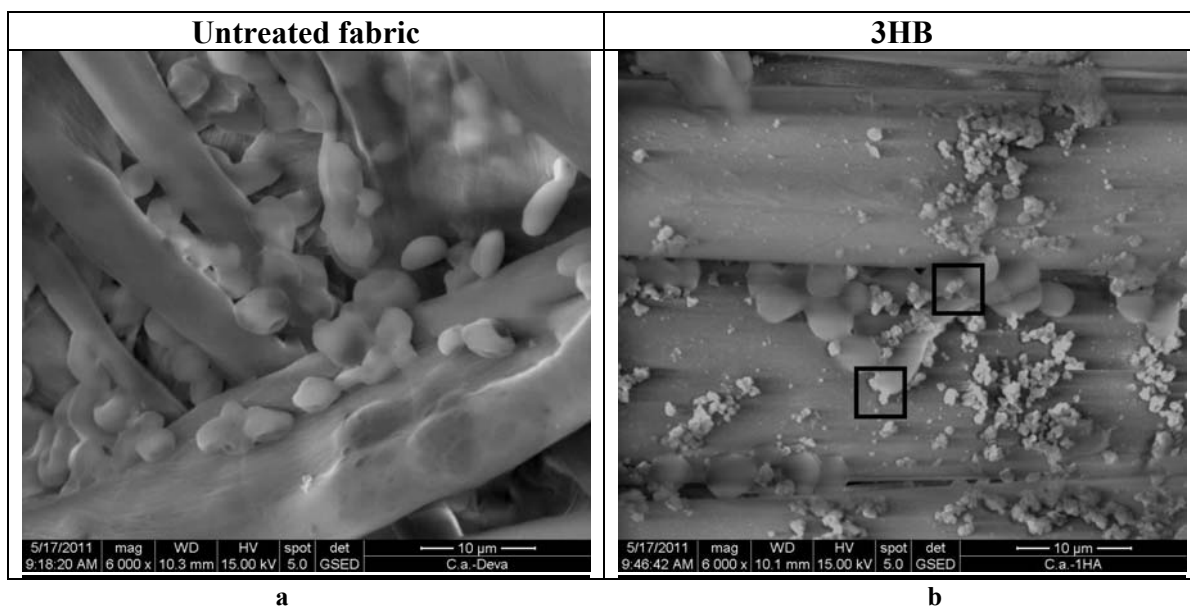


Figure 10: Interaction between TiO₂/Ag particles and yeast cells: a. untreated fabric; b. fabric treated with 1HA

5 CONCLUSIONS

Mechanical - physical properties of the fabrics treated with hydrophobins and TiO₂/Ag do not change noticeably, which leads to a high degree of breathability and comfort.

The hydrophobins, especially type A, form relatively uniform films on polyester fibres and less uniform on cotton ones. In time, hydrophobin A auto-assembles in a fibrillar form, with an α -helical structure, and hydrophobin B forms a thick film, with multiple aggregates, with a β - sheet structure. These structures are the ones that retain metal-oxide particles on the surface of the materials.

Purple staining, specific to amino-acids reaction with Nynhidrin, demonstrates that the hydrophobins are deposited on the fabric and that further treatment with metal-oxide particles doesn't remove the hydrophobin from the textile material.

Composite nanopowders based on TiO₂/Ag can be used as efficient antimicrobial agents for textile materials. The antimicrobial efficiency is higher when the silver concentration in particle composition increases, with the observation that with the growth of concentration, the fabric is stained more vividly.

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NOVEL APPROACH TOWARD OPTICAL SENSORS BASED ON ELECTROSPUN NANOFIBERS -QUANTUM DOT COMPOSITES

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Abstract: *It is widely approved that nanofibrous membranes formed by electrospinning process enjoy specific surface area approximately several order of magnitude larger than conventional thin films. This attitude makes electrospun composite nanofibers as prominent candidates for novel applications such as sensors. There are several sensing mechanisms that can be exploited to detect the trace of toxic chemicals or vapors which some of them include: optical, resistive, photoelectric, acoustic wave. The most convenient approach is optical sensing that the past 25 years have witnessed the growing research activity in optical sensing. We report the fabrication of highly sensitive quenching fluorescence based sensor for detecting trace of toxic volatile organic vapors like toluene. In this work, for the first time, fluorescent CdTe quantum dots were uniformly embedded in poly vinyl alcohol (PVA) nanofibers by electrospinning of quantum dot – PVA mixed solution and used as optical sensor. Surface morphologies and dimensions of PVA/ CdTe nanofibers were observed by SEM. The experimental results demonstrated that the quantum dot – PVA nanofiber composite poses not only high sensitivity but also fast time – response upon the exposure of toluene vapor.*

1. INTRODUCTION

2-6 semiconductor nanocrystals, known as quantum dots (QD) have been prompted much more attention due to their unique characteristics than organic dyes which suffer from fast photobleaching [1]. Some of promising traits of QDs are resistance to photobleaching, chemical stability, wide absorption, narrow and symmetric emission in visible range and tunable spectral properties[2,3] make them powerful materials used in promising applications like light-emitting diode (LED), nano laser, solar cells, wave guides, photo sensors, photo catalyst and biological application [4].

On the other hand, it is predicted that solid-state linear array of QDs have a prominent characteristic which will open up new opportunities for novel nano-scale implements like sensors [5,6] and solar cells [7,8]. In this regard, polymeric materials which have very good processability have provided great opportunity to produce one-dimensional matrices such as nanofibers. Electrospun nanofibers have specific surface approximately one to two orders of magnitude larger than flat films [9]. This characteristic make them ideal to use in novel applications especially sensors which have received tremendous interest for monitoring the amount of pollution in the environment in the recent years. It is accepted that an accurate sensor should enjoy features such as high sensitivity, selectivity, fast time response, stability, durability, reproducibility and reversibility. These properties mainly depend on the

characteristic of sensing materials which is used. There are various sensing techniques and principles that among the optical sensing have many advantages compared to traditional type of sensors, such as the absence of electromagnetic interference in sensing and electric contact in the probe and so on [9].

The past 25 years have witnessed the growing research activity in optical sensing. Especially, the measurement of the fluorescence intensity of luminophore, whose sensitiveness to a particular analyte is a common approach for fabricating high sensitive and selective sensors [10]. It is well approved that sensitivity of a sensor that detects analyte by interacting with molecules of analytes on the surface will increase with increasing surface area per unit mass [9]. All of the previous works used fluorescent Q.D for determining biological substances and chemicals in aqueous solution [11,12] or they used Q.D in cast films [13,14], but here, for the first time, we report the fabrication of highly fluorescence Q.D-PVA nanofibrous membrane as optical sensor for sensing toxic volatile organic vapor such as toluene.

Experimental part:

Our typical optical sensor were made by dissolving PVA granules in de-ionized water and mixing this solution with defined amount of CdTe nanocrystals followed by electrospinning of prepared solutions. For the sake of studding the effect of fiber diameter of membrane on the time response of sensor, three different concentration of PVA (10,12,15 % Wt) were prepared. The resulting clear homogenous solutions were used for electrospinning process at 18 kV and fibers gathered on a glass sheet. The distance between nozzle and collector was kept at 10 cm during electrospinning for all the samples.

RESULTS AND DISCUSSION

Characterizations of QD-PVA nanofibers

Nowadays, electrospinning has been widely used to produce fine fibers. Most of the recent studies have been dedicated to find optimum conditions to acquire nanofibers without any defects, but it is time to find novel application for prepared fine nanofibers. In this context, for the first time we used highly fluorescence Q.D-PVA nanofibrous composites as fast time- response optical sensor. Figure 1 displays the SEM image of the fibers formed at 18 kV. With increasing the concentration of the PVA in the solution, we attained nanofibers with smaller diameters.

Figure 1 SEM image of QD-PVA nanofibers produced from solutions with different concentrations of PVA. A) 10% PVA B) 12%PVA C) 15% PVA

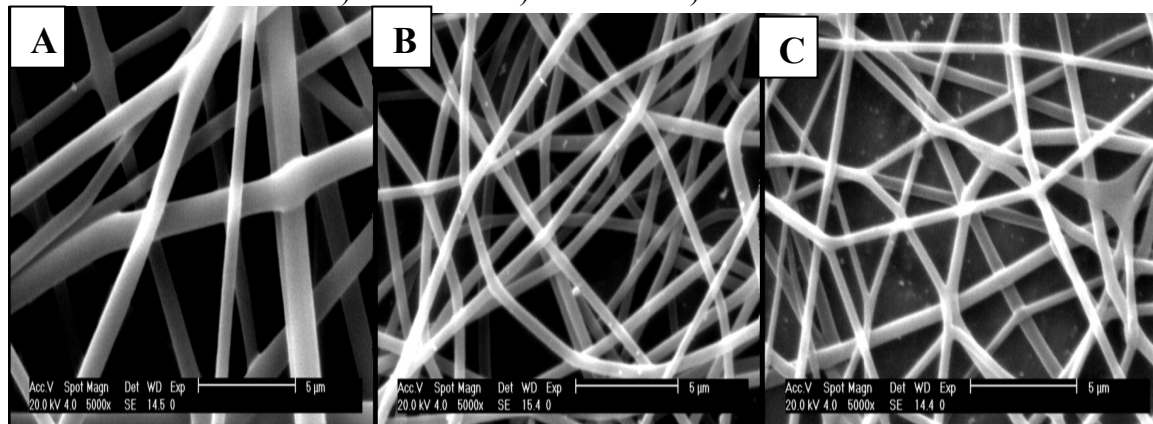


Table 1 shows the diameter of fibers which are electrospun from 10,12 and 15 % PVA solutions that contain QD

Table 1 the diameters of the fibers produced under different concentrations of PVA.

Sample	Fiber diameter/nm
10% PVA	453
12% PVA	680
15% PVA	996

As QDs are semiconducting, they cause the increased conductivity of electrospun solution. Table 2 shows the conductivity of 12 %wt solution of PVA which contains different amounts of QD water solution.

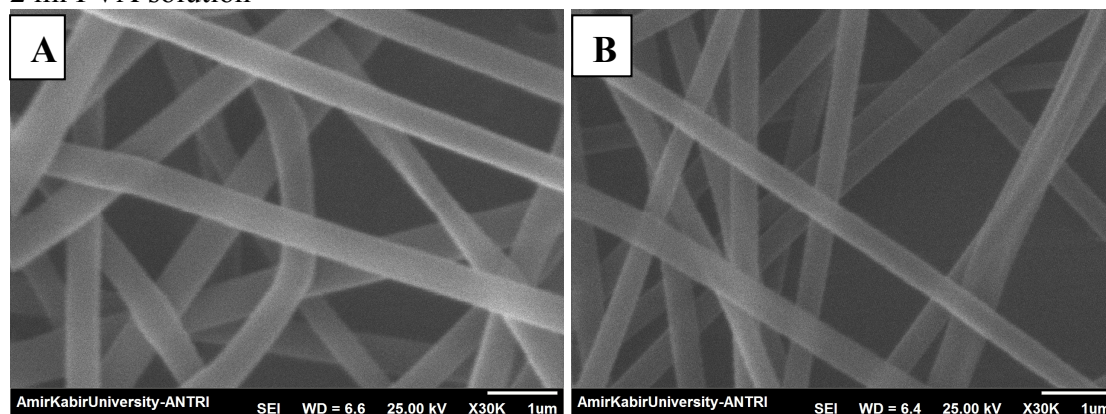
Table 2 conductivity of 12% PVA- water solution with different amounts of QD (the volume of all solutions of QD was kept at 3 ml)

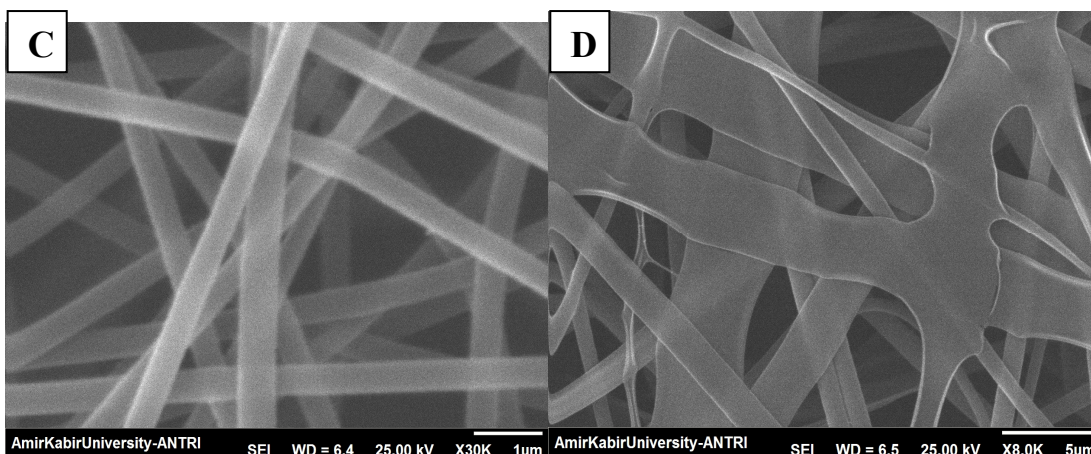
sample	Conductivity/micro siemens
Pure water	11.20
Pure 10^{-6} molar Q.D water solution	132.6
12%wt PVA- water solution	2.3
12%wt PVA- water solution with 0.1 ml Q.D	6.4
12%wt PVA- water solution with 0.5 ml Q.D	12.6
12%wt PVA- water solution with 1 ml Q.D	16.1

In order to study the effect of QD addition on morphology and diameter of nanofibers, four 12% wt PVA- water solutions containing 0, 0.1, 0.5 and 1 ml of water solution of QD were also electrospun. It should be mentioned that the volume of all solutions with QD were 3 ml.

Figure 2 shows the SEM image of nanofibers containing different amounts of QD.

Figure 2 SEM image of nanofibers containing different amounts of Q.D A) 0 m in 3 ml PVA solution l B) 0.1 ml in 2.9 ml PVA solution C) 0.5 ml in 2.5 ml PVA solution D) 1 ml Q.D in 2 ml PVA solution





the diameter of obtained nanofibers with different amounts of QD are reported in table 3.

Table 3 The diameters of nanofibers produced from 12%wt PVA water solution with different amounts of QD water solution.

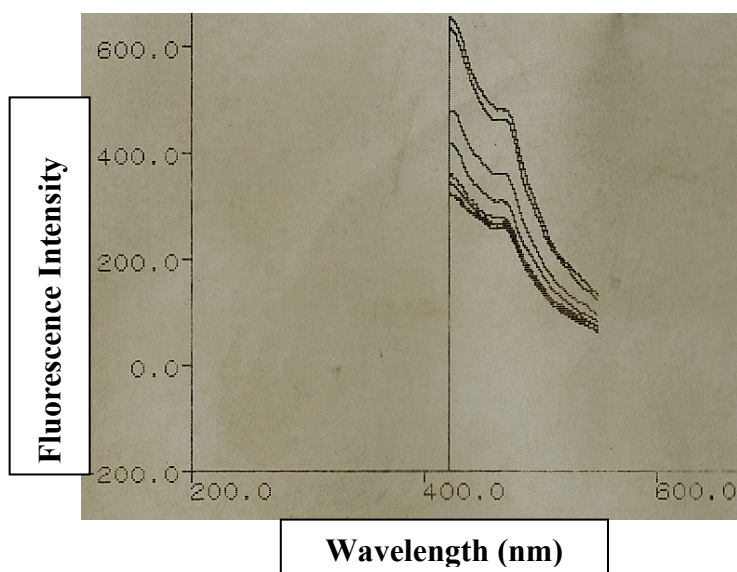
sample	Fiber diameter/ nm
Pure PVA	508
PVA/0.1 ml Q.D	403
PVA/0.5 ml Q.D	437
PVA/1 ml Q.D	1040

As it is expected with addition of QD into polymer solution, the diameter of nanofibers tends to decrease. For example, with the addition of 0.1 ml QD diameter of nanofibers decreases from 508 nm to 403 nm that this is mainly due to the increase of surface charge which causes the whipping instability of jet increases and consequently, the diameter of fiber decreases. On the other hand, with adding more amount of Q.D again the diameter of nanofibers tends to increase because of duality effect of increasing surface charge. With increasing the surface charge the time of soaring is decreased; hence, the fibers reach the collector sooner and there is less opportunity for jet to be stretched during the electrospinning process. Furthermore, there is no sufficient time for solvent to be evaporated completely and these phenomenon cause ribbon like nanofibers obtained as it can be seen from figure 2, D.

Toluene vapor sensing properties of QD-PVA nanofibers

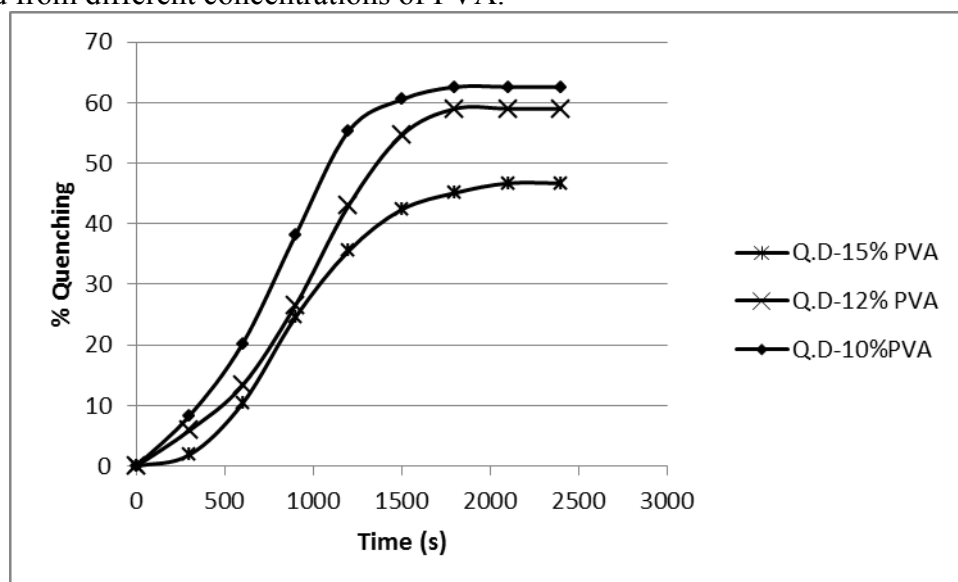
For the sake of toluene vapor sensing, 0.5 ml toluene was transferred to a 3 ml cuvette with a cap. A glass slide which is coated with electrospun Q.D-PVA nanofibers was cut and very carefully placed into this cuvette. There was no contact between glass slide and toluene surface in the cuvette. These conditions prevent direct contact of fiber- coated glass slide with toluene which causes error. Moreover, a constant saturation vapor pressure of toluene was gained. Afterwards, time-dependent fluorescence spectra were measured at an excitation wavelength of 350 nm. Fluorescence quenching was observed for all the Q.D-PVA nanofibers upon trace of toluene vapor. Figure 3 illustrates changing the fluorescence intensity of nanofibrous upon exposure of toluene vapor with time intervals of 5 minutes.

Figure 3 fluorescence emission spectra of electrospun membrane upon exposure of toluene vapor



As it can be seen upon the exposure of toluene vapor the fluorescence intensity starts to decrease until toluene vapor was satiated in the close-capped cuvette. Furthermore, membranes with smaller diameters exhibit higher sensitivity (expressed as present of quenching) upon trace of toluene vapor. Figure 4 displays the time dependence of fluorescence intensity of three membranes produced from different concentration of PVA upon exposure to toluene vapor. Using smaller nanofibers causes more QDs are located at the surface of nanofiber. In this case, more QDs are available to be quenched as toluene vapor reach them, but cast films do not have such ability. In fact, cast films abstain vapor permeate inside them.

Figure 4 The time-dependent fluorescence quenching of QD-PVA nanofibrous membrane produced from different concentrations of PVA.



CONCLUSION:

In this work, fluorescent QD-PVA nanofibrous membrane was successfully fabricated and used, for the first time as highly sensitive and fast time response optical sensor to detect toxic volatile organic vapors, such as toluene. The results of performed experiments suggest that the morphology and diameter of nanofibers in the membrane have extreme effect on

sensing properties of the fabricated optical sensor. Reducing the diameter of nanofibers endows better permeability of vapor into the membrane and results in better and faster vapor sensing. We believe that this kind of sensor will open up new and alternative perspectives towards the fabrication of not only high sensitive but also selective sensors. In this regard, our research around this subject will continue very aggressively.

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HIGHLY CONCENTRATED COLLOIDAL SILVER SOLUTIONS FOR ANTIMICROBIAL FUNCTIONALIZATION OF SOME TEXTILES AND LEATHERS

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Keywords: colloidal silver solutions, chemical synthesis method, antimicrobial properties

Abstract. *The paper presents the research results for creating some stable colloidal silver solutions of high concentration by an original and efficient chemical synthesis method. It consists of chemical reduction of silver ions from aqueous silver nitrate solutions using sodium borohydride solutions and a stabilizer agent of anionic polyelectrolyte type such as poly(4-styrenesulfonic acid-co-maleic acid) sodium salt. The reaction was carried out in suitable conditions relating to concentration, temperature, pH, dropping rate and stirring. After that some antimicrobial functionalized textiles and leathers were prepared. The colloidal silver solutions were characterized from chemical and physical point of view. Moreover, the colloidal silver solutions and functionalized materials were tested for the antimicrobial (antifungal and antibacterial) activity according to the standards in force. The AgNps concentration and light absorbance were determined by UV-Vis spectrophotometry technique. The grain size and shape of AgNps were determined using a transmission electronic microscope. The mean diameter, grain size distribution of AgNps, pH and stability of solutions were analyzed by Dynamic Light Scattering method. The antimicrobial tests proved that the obtained colloidal silver solutions and functionalized materials have a high biological activity.*

1. INTRODUCTION

During the last twenty years, silver nanoparticles (AgNps) were extensively investigated due to the attractiveness of their unique physical properties, chemical reactivity, and potential applications with high academic and industrial impacts. Besides these properties, AgNps can present an antimicrobial activity depending on their shape, size and concentration, inhibiting the growth and multiplication of broad ranges of germs, viruses, bacteria, allergens and pathogens ^{1, 2, 3, 4}. Also, CSSs have anti-inflammatory and regenerative effects ⁵.

These excellent properties recommend AgNps for use in many textiles and leather products ^{6, 7, 8}. The treatment of textile and leather materials with AgNps containing coatings is of a high economic interest, especially because of their applications in the medical field.

Numerous synthesis methods have been reported in the literature for the preparation of AgNps. Conventionally, CSSs can be produced by chemical reduction of Ag⁺ ions, thermal decomposition in organic solvents, electrochemical or photochemical reduction in reverse

micelles^{9, 10, 11, 12, 13}. However, most of these methods have some inherent problems in particles size controllability, colloidal stabilities, scalability of the production and cost. While each method has certain advantages and disadvantages, the selection of a proper synthetic procedure depends on the nature of the AgNps application¹⁴.

In our research works we focused on an original and efficient chemical method for the AgNps synthesis in presence of surfactants of anionic polyelectrolyte type, which by their structure include strong anionic group (sulfonate group) and weak anionic group (carboxylic group) and thus allow obtaining of highly concentrated and stable suspensions in comparison with other ionic or polymeric stabilizers. This is due to strong interactions of polyelectrolyte-metal type that are set for the ionic state of silver, as well as for the reduced one.

The obtained highly concentrated CSSs were used to antimicrobial functionalization of some textile and leather materials.

2. EXPERIMENTAL PART

2.1. Materials

The following materials were used in experiments: bi-distilled water with pH = 5.5 and electrical conductivity of 5 μ S at 25 °C; silver nitrate aqueous solutions of 0.4...0.8 wt. % concentrations (AgNO₃, p.a., crystallized, \geq 99.9 %, Fluka); poly(4-styrenesulfonic acid-co-maleic acid) sodium salt (PSSA-co-MA) solutions of 1...2 wt. % concentrations (C₁₂H₁₀Na₂O₇S with 4-styrenesulfonic acid: maleic acid mole ratio of 1:1, M_w ~ 20,000, Aldrich) and sodium borohydride solutions of 0.1 wt. % concentration (NaBH₄ \geq 96 %, M_w = 37.83, Merck).

2.2. Synthesis

The CSSs were synthesized by reduction of Ag⁺ ions from an AgNO₃ aqueous solution with a NaBH₄ solution in presence of the PSSA-co-MA polyelectrolyte used as protective agent in proper conditions relating to concentration, temperature, pH, dropping rate and stirring. The PSSA-co-MA solution was added drop wise to the AgNO₃ aqueous solution, which was previously heated at 70...90 °C and vigorously stirred. After a light yellow colour appeared, the suspension was rapidly cooled and kept at 4 °C. Then the NaBH₄ solution was slowly added drop wise in the suspension and kept for 0.5...1 h under vigorous stirring. The NaBH₄:AgNO₃ molar ratio was of 2:1.

2.3. Characterizations

The AgNps concentration was determined by spectrophotometry technique by measurement of light absorption at the fixed wavelength of 398 nm using the calibration curve that was drawn at the highest absorption intensity by a spectrophotometer (model V-570, Able & Jasco, Japan). Also, the UV-Vis absorbance spectra were recorded with the same spectrophotometer using a scanning speed of 100 nm/min.

The grain size and shape of AgNps were determined using a transmission electronic microscope (model CM100, Philips, Holland).

The average diameter of AgNps, grain size distribution, pH and zeta potential of the CSSs were measured by Dynamic Light Scattering (DLS) method using a nanoparticles size analyzer (model 90 Plus with BI-Zeta option, Brookhaven, USA).

2.4. Functionalization of some textiles and leathers

The functionalization of some textile and leather materials was performed by three successive dipping of these materials in the CSSs, followed by intermediary drying of the materials before the next dipping.

The textile material used in experiments was of 100 % cotton absorbent gauze for medical products.

The leathers were previously treated with chromium, then washed and subsequently functionalized with AgNps.

2.5. Antifungal activity tests

The antifungal effectiveness of the CSSs and AgNps functionalized materials was tested by the antibiogram method according to the conditions of standards SR EN 60068-2-10:2006 and SR EN 1275:2006, using a mould mixture of *Aspergillus niger*, *Penicillium funiculosum*, *Paecilomyces variotii*, *Chaetomium globosum*, *Scopulariopsis brevicaulis* and *Trichoderma viride*. In this aim, a 10 mm diameter filter paper was immersed in the CSSs. As inoculum, a suspension of the above-mentioned spores in the complete Czapek-Dox mineral salts solution (with sucrose as an additional source of C) was used. The incubation time was of 28 days and the samples were studied after 4 days, 7 days, 14 days and 28 days from the moulds inoculation using a stereomicroscope with magnification of x 50.

2.6. Antibacterial activity tests

The antibacterial activity tests of the CSSs were carried out by the agar microdilution method, according to the standard SR EN 1040:2006, against some common and aggressive bacterial strains: *Staphylococcus aureus* ATCC 6538, *Escherichia coli* ATCC 8739, *Pseudomonas aeruginosa* ATCC 9027, *Serratia marcescens*, *Enterobacter cloacae*, *Acinetobacter baumannii*, *Escherichia Coli* ESBL and *Klebsiella pneumoniae*. In this respect, the determination of Minimum Inhibitory Concentration (MIC) was performed to find out the AgNps lowest concentration that inhibits the visible growth of the test microorganisms.

3. RESULTS AND DISCUSSION

Figure 1 presents the calibration curve of the CSSs. It is of proportional type, being represented by the relation no. (1), where Abs. [a.u.] is the absorbance, and Conc. [ppm] is the concentration:

$$\text{Abs} = 0.095 * \text{Conc.}$$

(1)

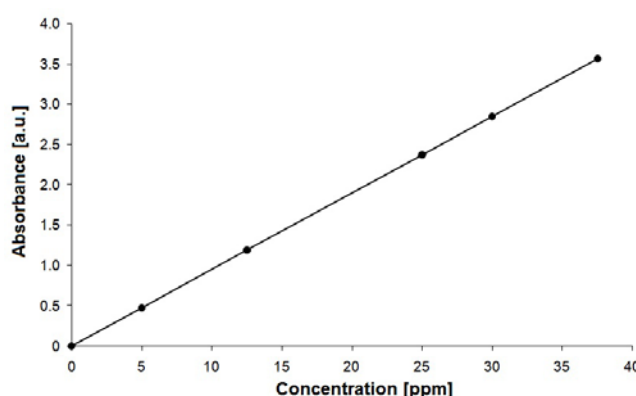


Figure 1: Calibration curve.

The results of the CSSs concentration measurements were as expected, being included within the tolerance limits of $\pm 2\%$ of the theoretical yield calculated values.

It is known that the UV-Vis spectroscopy is a valuable tool for structural characterization of AgNps. In AgNps the conduction band and valence band lie very close to each other in which electrons move freely. These free electrons give rise to a surface plasmon resonances (SPR) absorption band, occurring due to the collective oscillation of electrons of AgNps in resonance with the light wave. When the frequency of the electromagnetic field becomes resonant with the coherent electron motion, a strong absorption takes place, which is the origin of the obtained colour of both CSSs that is dark reddish brown. Also, it is well recognized that Ag is the only material whose SPR can be tuned to any wavelength in the visible spectrum¹⁵. In general, the number of SPR peaks decreases as the symmetry of the nanoparticle increases.

Figure 2 presents the UV-Vis spectra of absorbance versus wavelength (Figure 2 a) and energy (Figure 2 b) of the CSSs with concentration of 1500 ppm AgNps and 3000 ppm AgNps.

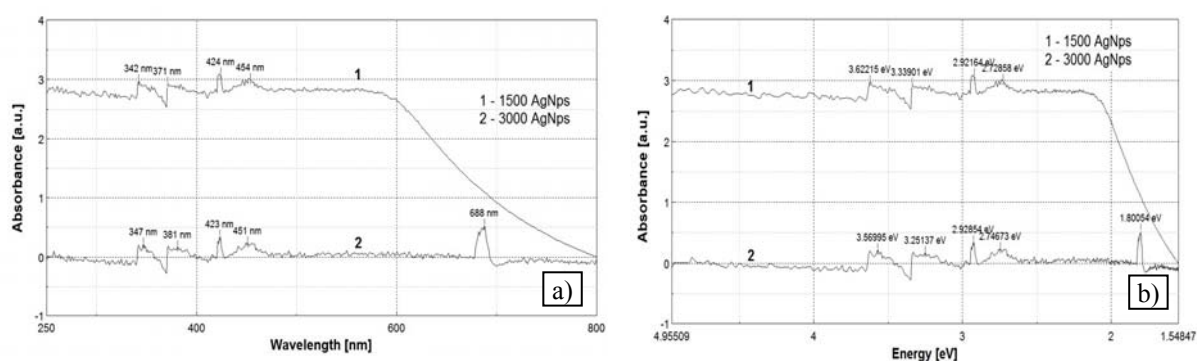


Figure 2: UV-Vis spectra of absorbance versus wavelength (a) and energy (b) of the CSSs with concentration of 1500 ppm AgNps (1) and 3000 ppm AgNps (2).

The UV-Vis absorbance spectrum of the CSS with concentration of 1500 ppm AgNps presents absorption peaks at intensities of 3.012 a.u., 3.105 a.u., 2.947 a.u. and 2.998 a.u. that correspond to wavelengths of 454 nm, 424 nm, 371 nm and 342 nm. Also, the UV-Vis absorbance spectrum of the CSS with concentration of 3000 ppm AgNps presents absorption peaks at intensities of 0.548 a.u., 0.247 a.u., 0.361 a.u., 0.185 a.u. and 0.231 a.u. that correspond to wavelengths of 688 nm, 451 nm, 423 nm, 381 nm and 347 nm. These spectra (Figure 2 a) correspond with the ones depending on the energies (Figure 2 b) because light is energy, and when energy is absorbed by AgNps it results in a change in energy levels of the AgNps.

Absorbance is directly proportional to concentration of particles and it is decreasing with the increasing concentration of AgNps. At the CSS with concentration of 3000 ppm AgNps, which has a double concentration of AgNps than the other CSS, the AgNps are more strongly capped reducing in this way their UV-Vis absorption capability and also due to the increasing of the AgNps size a red shift occurred at 688 nm.

The wavelengths of the peaks are very little differentiated for both CSSs while the absorption intensities are higher in the case of the CSS with concentration of 1500 ppm AgNps. The agglomeration tendency of AgNps is increased for the CSS with concentration of 3000 ppm AgNps, in comparison with the one of 1500 ppm AgNps.

The concentrated CSSs are soluble in cold or warm water and can be diluted at any desired concentration. For example, Figure 3 presents the UV-Vis absorbance spectra of the CSSs with concentration of 50 ppm AgNps diluted from both concentrated CSSs.

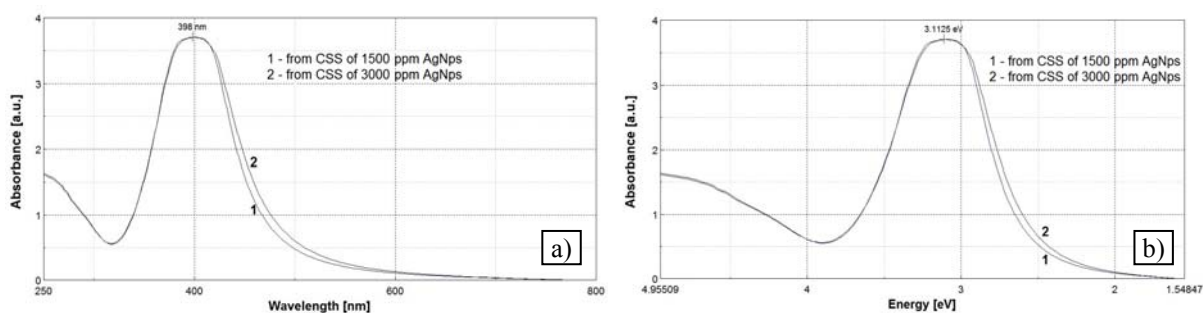


Figure 3: UV-Vis spectra of absorbance versus wavelength (a) and energy (b) of the CSSs with concentration of 50 ppm AgNps diluted from the concentrated CSSs of 1500 ppm AgNps (1) and 3000 ppm AgNps (2).

The AgNps from the CSSs diluted at 50 ppm NpAgs from the highly concentrated CSSs of 1500 ppm NpAgs and 3000 ppm NpAgs had a sharp absorption peak at 398 nm, which is characteristic of SPR of the AgNps. The recorded spectra for both diluted samples had almost the same shape, and the same absorbance intensity of 3.717 a.u. that corresponds to a wavelength of 398 nm (Figure 3 a), namely to an energy of 3.1125 eV (Figure 3 b).

Figure 4 presents the TEM images of AgNps from the CSS with concentration of 1500 ppm AgNps, respectively of 3000 ppm AgNps. The AgNps are spherical in shape with a smooth surface morphology. The diameter of the AgNps is found to be about 8 nm and 14 nm in the case of the CSS with concentration of 1500 ppm AgNps, respectively of 3000 ppm AgNps. It is observed that AgNps tend to be agglomerated for the most concentrated CSS.

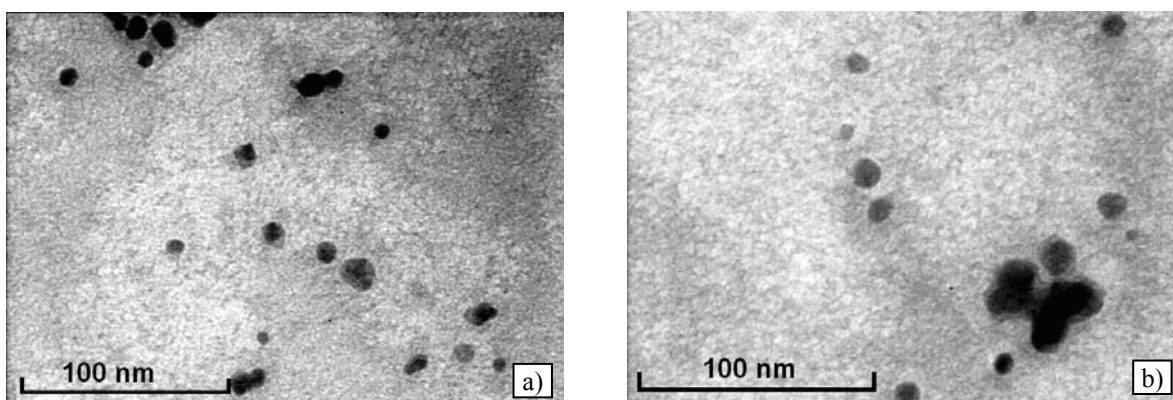


Figure 4: TEM images of the CSS with 1500 ppm AgNps (a) and 3000 ppm AgNps (b).

In Figure 5 are presented the grain size distributions of the AgNps performed on samples diluted at 50 ppm AgNps from the CSSs of 1500 AgNps, respectively 3000 ppm AgNps.

The average diameter of AgNps was of 9.2 nm and of 15.1 nm for the CSS with concentration of 1500 ppm AgNps, respectively of 3000 ppm AgNps.

The grain size distribution of AgNps is in a narrow range for the both CSSs.

The data obtained for the average diameter of AgNps are in agreement with TEM analyses (Figure 4). The fine average diameters led to a high surface area of AgNps that can contribute to the achieving of a high antimicrobial activity of the CSSs.

The stability of the CSSs is determined by both Van der Waals attractive forces and electrical double layer repulsive forces that exist between particles as they approach each other due to the Brownian motion they are undergoing.

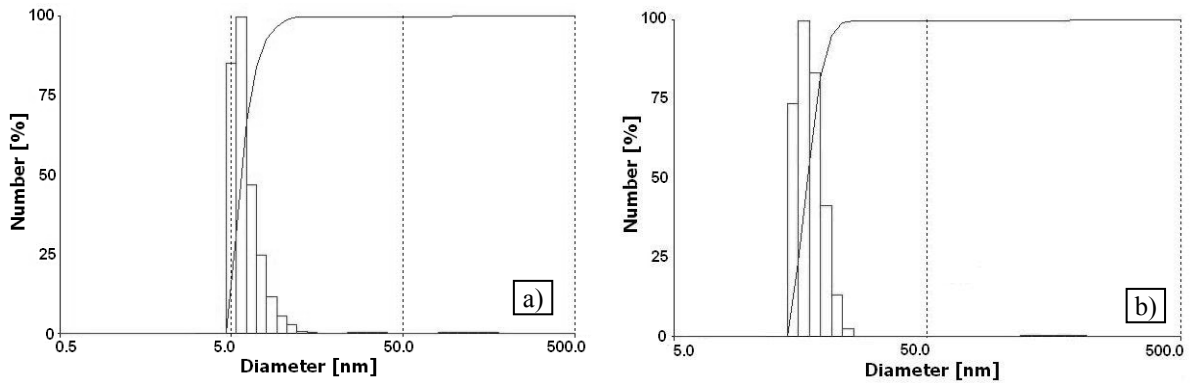


Figure 5: Grain size distribution of the AgNps in the CSS of 1500 ppm AgNps (a) and 3000 ppm AgNps (b).

Since zeta potential is a measure of the repulsive forces in electrostatically - stabilized systems, it is an excellent indicator of relative stability. The sign and magnitude of zeta potential, as a function of pH, salt, or dispersing agent concentration are indicators of stability against flocculation or coagulation¹⁶.

The magnitude of the zeta potential gives an indication of the potential stability of the CSSs. The colloidal suspensions with zeta potentials more negative than -30 mV and more positive than +30 mV are normally considered stable¹⁷.

Figure 6 presents the zeta potential curves (measurements of colloidal solution stability by the electrostatic repulsion between nanoparticles) of the CSSs with concentration of 1500 ppm AgNps and 3000 ppm AgNps and pH of 8.8...9 for the both CSSs.

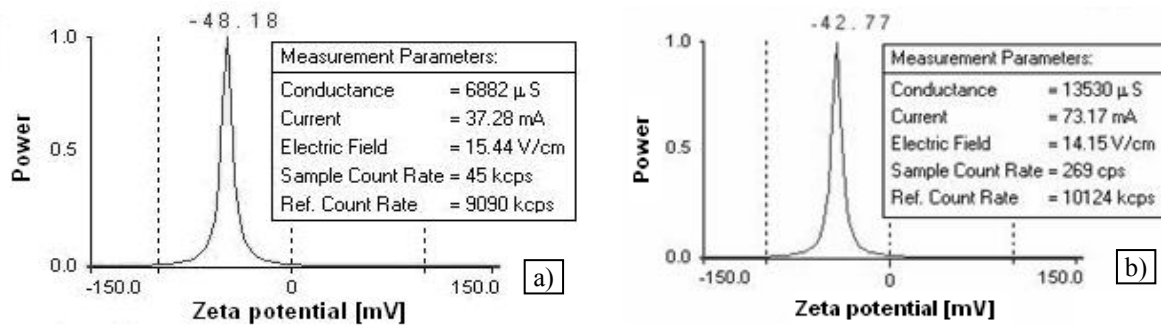


Figure 6: Zeta potential of the CSS with concentration of 1500 ppm AgNps (a) and 3000 ppm AgNps (b).

The zeta potential of the CSS of 1500 ppm AgNps (-48.18 mV) and of the CSS of 3000 ppm AgNps (-42.77 mV) are more negative than -30 mV, so the obtained CSSs are stable. Since the AgNps from the both CSSs have a large negative zeta potential, they tend to repel each other and in this way there is no tendency for AgNps to come together.

The high stability of the CSSs is the result of the used chemical method for the AgNps synthesis that controls the size and the dispersion of the AgNps by reducing the surface energy through the stabilization with PSSA-co-MA, which contains strong anionic group (sulfonate group) and weak anionic group (carboxylic group). The dispersion mechanism of the PSSA-co-MA is mainly controlled by electrostatic repulsion that is assured by the sulfonate styrene units. The copolymer added in system adsorb onto the particle surface, preventing the particle surfaces coming into close contact to keep particles separated by steric repulsion. Also, the PSSA-co-MA chains present in the solution interfere with AgNps

formation leading to enhanced steric stabilization.

Since the AgNps stabilized with PSSA-co-MA have a high charge density and therefore their zeta potentials are very negative, it led to obtaining of high concentrated and stable CSSs.

Table 1 presents the antifungal properties of the obtained CSSs and some functionalized textile and leather materials with CSS of 1500 ppm AgNps.

Sample	Behavior at moulds action				
	Marks from 0 – 5 / Inhibition zone [mm]				
	4 days	7 days	14 days	28 days	
CSS of 1500 ppm AgNps	0 / 4	01-1 / 3	1 / 3	1 / 3	
CSS of 3000 ppm AgNps	0 / 4	0 / 3	0 / 3	0 / 3	
Functionalized textile with CSS of 1500 ppm AgNps	0 / -	0 / -	01 / -	01 / -	
Functionalized leather with CSS of 1500 ppm AgNps	front	0 / -	01 / -	3 / -	4 / -
	reverse	0 / -	1 / -	3 / -	3 / -

Table 1. Antifungal properties of the obtained CSSs and some functionalized textile and leather materials with these CSSs, where 0 = no mould growth; 1 = growth barely visible with the naked eye, but visible under a microscope;

2 = growth covering more than 25 % of the sample surface; 3 = growth of mould that covers between 25 % and 50 % of the surface; 4 = growth covering over 50 % of the surface; 5 = growth covering the entire surface of the sample.

Figure 7 and Figure 8 present the digital images of the CSS of 1500 ppm AgNps, respectively of the CSS of 3000 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

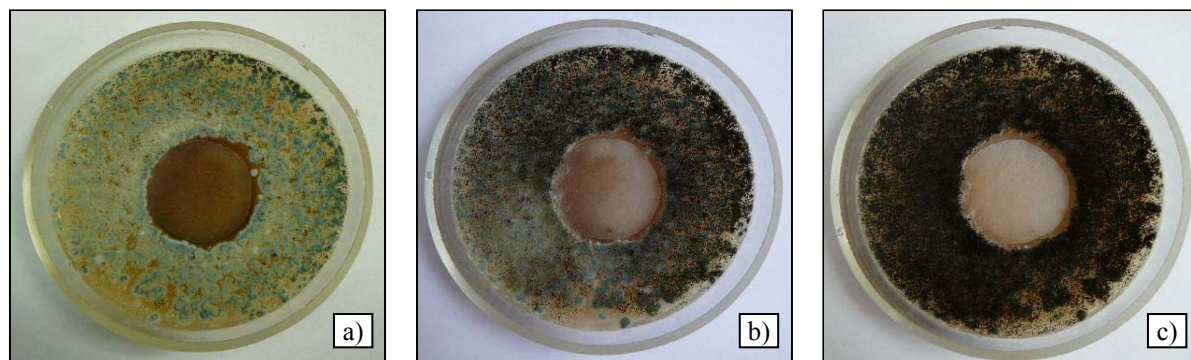


Figure 7: CSS of 1500 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

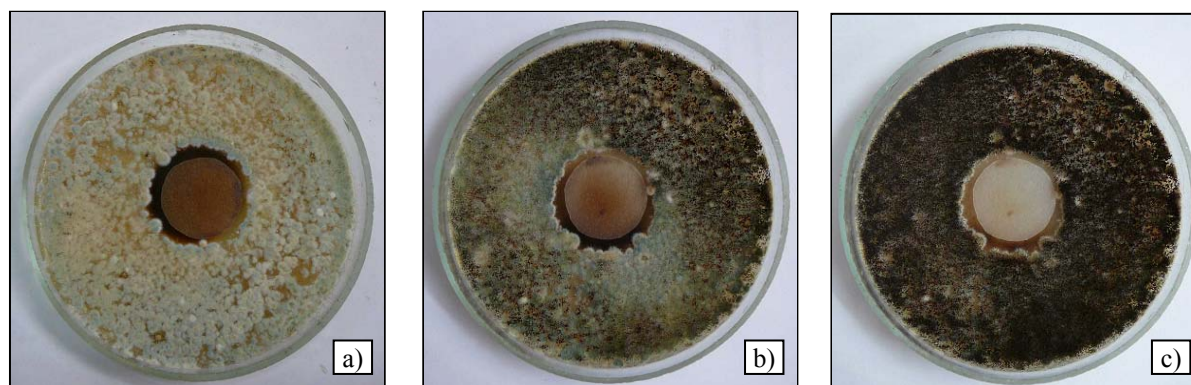


Figure 8: CSS of 3000 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

From Figure 7 and 8 it is noticed that after 4 days from the moulds inoculation both CSSs have a high fungistatic effect with no mould growth on the sample (mark of 0) and an inhibition zone of 4 mm.

After 7 days from the moulds inoculation, the inhibition zone of moulds growth is slightly decreased with 1 mm, proving in this way the decreasing of the fungistatic effect on time. The highly concentrated CSS of 3000 ppm does not have any moulds growth while the one of 1500 ppm AgNps presents a growth of some micromycetes colonies visible under the stereomicroscope. The highest fungistatic effect was obtained at the most concentrated CSS.

After 14 days and 28 days from the moulds inoculation the both CSSs still have a high fungistatic effect and the inhibition zone remained unchanged at 3 mm. The CSS of 3000 ppm AgNps did not present any mould growth (mark of 0) while the CSS of 1500 ppm AgNps presented a growth of *Trichoderma viride*, *Aspergillus niger* and *Paecilomyces variotii* fungi on the sample that was visible only under the stereomicroscope (mark of 1).

Figure 9 and Figure 10 present the digital images of some functionalized textile and leather materials with CSS of 1500 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

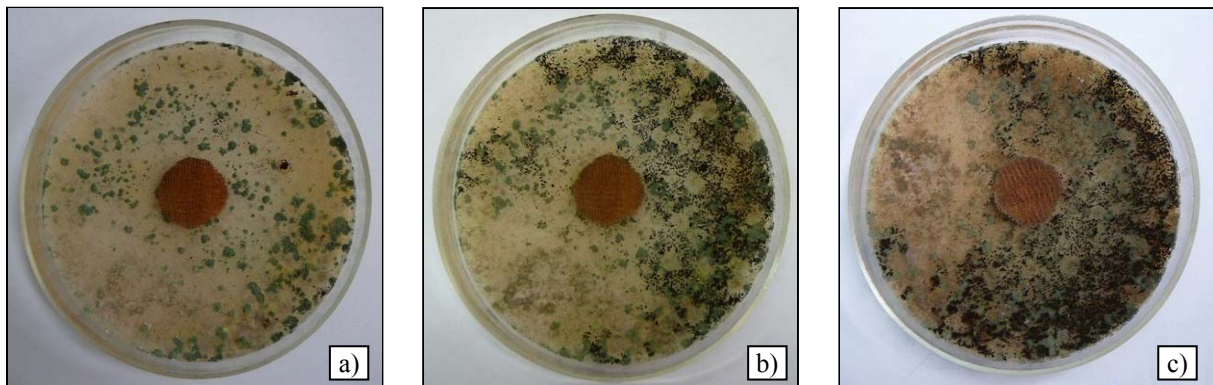


Figure 9: Functionalized textile with CSS of 1500 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

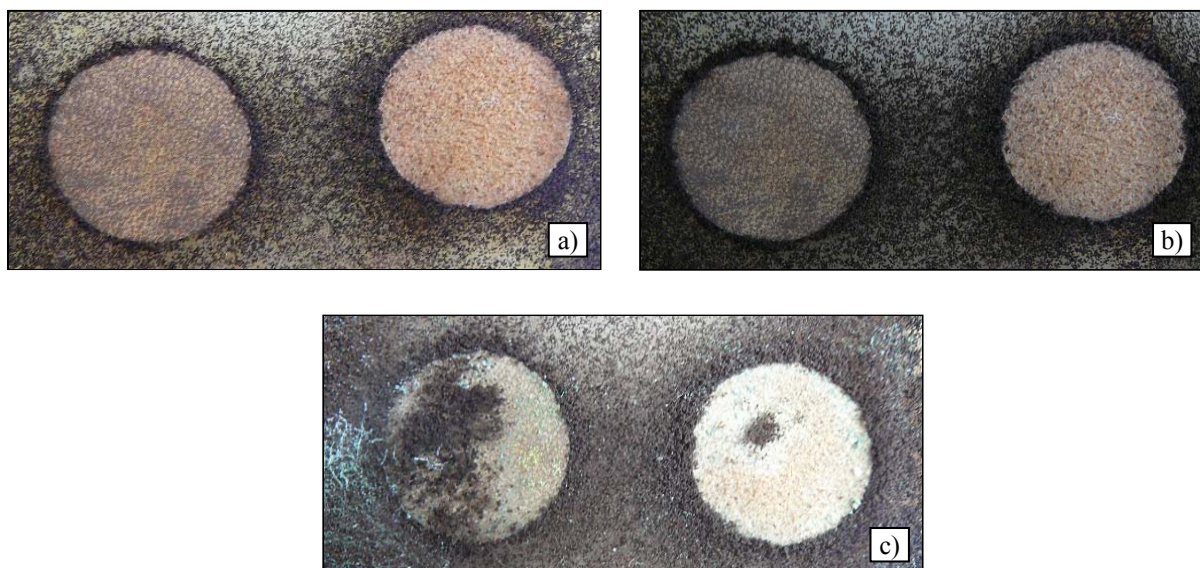


Figure 10: Functionalized leather (left side front, right side reverse) with CSS of 1500 ppm AgNps after 4 days (a), 7 days (b) and 28 days (c) from the moulds inoculation.

From Figure 9 it is noticed that after 4 days and 7 days from the moulds inoculation there is no mould growth on the sample, with less bacteria within a radius of 10 mm around the

sample after 4 days.

A highly fungistatic effect of the AgNps functionalized textile material was obtained after 4 days and 7 days from the moulds inoculation (mark of 0) that was maintained further up to 28 days from the moulds inoculation (mark of 01). There was no inhibition zone around the sample in all 28 days of testing, and some hyphae and *Aspergillus niger* mould were observed on the edge of the sample after 14 days from the moulds inoculation.

The results obtained from the antifungal activity tests for the functionalized leather with CSS of 1500 ppm NpAgs (Figure 10) showed a good behaviour in the first 7 days (marks of 0 and 01), then the antifungal activity decreases below the allowed limit (marks of 3 and 4). The predominant species that grew on the sample were *Aspergillus niger* and *Trichoderma viride*.

Table 2 presents the minimal inhibitory concentration of the CSSs with concentration of 1500 ppm AgNps and 3000 ppm AgNps against the tested strains.

Sample	Tested strains / Minimal inhibitory concentration (MIC) [ppm]							
	S. aureus ATCC 6538	E. coli ATCC 8739	Pseudomonas aeruginosa ATCC 9027	Serratia marcescens	Enterobacter cloacae	Acinetobacter baumannii	E. Coli ESBL	Klebsiella pneumoniae
CSS of 1500 ppm AgNps	< 18.8	< 18.8	75	< 18.8	< 18.8	< 18.8	< 18.8	< 18.8
CSS of 3000 ppm AgNps	< 18.8	< 18.8	75	< 18.8	< 18.8	< 18.8	< 18.8	< 18.8

Table 2. Minimal inhibitory concentration of the obtained CSSs against the tested strains.

The results obtained from the antibacterial activity tests of both CSSs showed a very good activity against all tested strains, proving their broad spectrum antimicrobial activity.

These results are in accordance with the results obtained at the antifungal assessments.

3. CONCLUSIONS

The research works were focused on the obtaining of some stable colloidal silver solutions of high concentration by an original and efficient chemical synthesis method that can be up-scaled successfully both in textile and leather industry and in other industries, too.

The obtained colloidal silver solutions were characterized from the point of view of absorbance in UV-Vis, pH and stability, average diameter, grain size distribution and shapes of silver nanoparticles. Also some antimicrobial tests were performed.

UV-Vis spectroscopy revealed the surface plasmon property, while DLS measurements and TEM images revealed the nano nature of the prepared samples.

The antimicrobial tests proved a high biological activity of the obtained colloidal silver solutions and functionalized materials against a broad spectrum of moulds and strains.

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VAT DYEING OF JUTE FIBERS AND EFFECT OF HYDROPHILING ENZYME TREATMENT

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Keywords: Vat dyeing, jute fibers, enzyme, pectinase

Abstract: *Jute fiber is an environmental friendly alternative for synthetic fibers due to its ecological benefits. Besides its technical textile uses, jute fiber has a rising usage on home textiles especially in furniture industry. High fastness values are generally required for furniture textiles since these materials are used under tough conditions. For instance, outdoor furniture is highly exposed to sunlight so it is expected to have high light fastness values. In this study, the dyeing behavior of vat dyes on jute fiber is investigated. Four vat dyes (3 IW, 1 IN) are applied in pale and heavy depth of shades. The effect of pectinase enzyme on color properties is also investigated. Colorimetric measurements and fastness properties are determined.*

1 INTRODUCTION

Jute is the second most consumed natural fiber in the world after cotton (2007 production is 2.878.030 tons) [1-2]. Conventionally, jute fiber is used for packaging materials, carpet backings, twines and ropes etc. [2-6]. However, now, uses of jute fiber are diversified and the jute becomes a preferred fiber instead of synthetic fibers due to environmental benefits and biodegradable property of jute fiber [2-3-4-5-6]. Most of the negative properties of jute fiber can be eliminated today by different chemical applications and finishing processes. This situation results in the combination of eco-friendly and superior performance properties of jute leading to more valuable products [2-6]. Home textiles and furniture industry are the important examples for jute fiber usage [6]. These uses of fabrics require high fastness values and vat dyes can be a good choice for such high fastness requirements [7].

Vat dyes are very important dye class for cellulosic fiber dyeing. This dye class provides very high fastness properties which cannot be covered by any other dye classes [7-8]. These high fastness properties are not only available for daily use but also available for some special factory processes such as mercerizing and bleaching after vat dyeing [7]. So vat dyes are suitable for high fastness required products, such as: workwear and uniforms, clothing, sportswear, home textiles, furnishing and outdoor fabrics etc. [7]

Jute has some non-cellulosic impurities in raw fiber form like lignin, pectin and hemicellulose [9]. These impurities are eliminated by conventional alkali scouring processes. However, alkali application has some disadvantages. Alkali scouring and caustic soda treatment cause weight loss and fiber damage. Also, the chemicals that are used in alkali process are hazardous for environment. Today, pectinase enzymes are widely used in the scouring of cellulose fibers as an alternative to intensive chemical usage. Pectinases hydrolyze pectin into galacturonic acid and little sugars and do not harm cellulose molecules. Cotton fabric gives better wetting and penetration properties after enzyme scouring process. This leads to better dyeing behavior [10]. Pectinase is also used for retting and degumming of

fiber crops [11].

In this study, jute fabrics were dyed with vat dyes to achieve high fastness values. Also, the bio-scouring treatment was carried out with pectinase enzyme. The effect of enzyme treatment to vat dyeing of jute was investigated.

2 EXPERIMENTAL

2.1. Fabric

%100 jute plain woven greige fabric was used.

2.2. Bleaching

Jute fabric was bleached before the enzyme treatment. A combination of cold and exhaustion bleaching was carried out. Bleaching procedures and chemical usage are shown below;

Cold bleaching;

Speed: 45 m/dk

Time: 16 hours

40 gr/lit Caustic soda (38° BE)

60 gr/lit Peroxide (%50)

4 gr/lit COTTOCLORIN OK (Wetting agent)

2 gr/lit FORLY LFO CONC (Fat remover)

18 gr/lit MNEU STAB (Stabilizer)

Exhaustion bleaching;

Time: 45 minutes

Temperature: 95°C

Liquor Ratio: 1:7

2 gr/lit Caustic soda

2 gr/lit Peroxide

0.8 gr/lit COMBINO F5

0.4 gr/lit PERNOX SPR (Anti-peroxide)

1 gr/lit Acetic Acid

2.3. Enzyme Treatment

Modified pectinase enzyme (Scourzyme L by Alfakimya) was used at % 0.4 concentration for the bio-scouring of jute fabric. Enzyme treatment was carried out at ATAC LAB DYE-HT laboratory type exhaustion dyeing machine. Liquor ratio was 1/10. Wetting agent usage was 1 ml/l. pH 8,2 is adjusted with soda for enzyme activation. Enzyme treatment procedure can be seen on Figure 1.

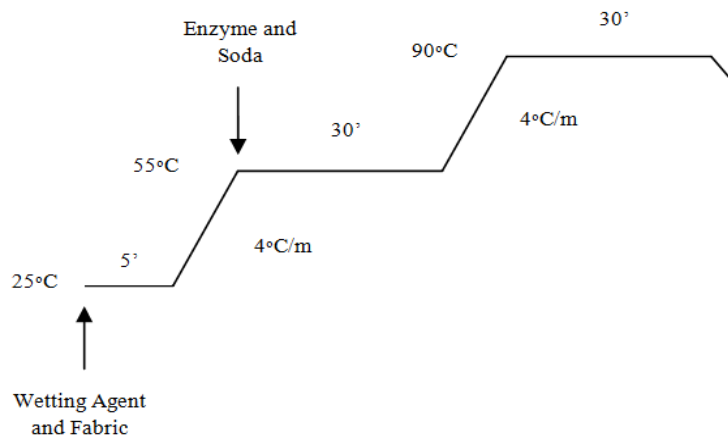


Figure 1: Enzyme treatment procedure

After the enzyme treatment, samples were rinsed with hot and cold water and then they were air-dried.

2.4. Dyeing

The basic principle of vat dyeing is to reduce water-insoluble keto-substituted colorant to obtain water-soluble leuco form which has affinity to cellulose. Reoxidation step follows penetration of dyes into the fiber. Dye becomes insoluble in the fiber by oxidation and turns back to the original form [28].

Vat dyes are classified according to alkali and reducing agent requirement and suitable dyeing temperature. One of these is IK, IW, IN and IN Special classification system. The I standard is for Indanthrene dyes which is an important trade mark. The details of this classification can be seen below [7-8].

IK dyes: This group has low substantivity to cellulose and they are applied at room temperature. Small amount of alkali is used with high amount of salt.

IW dyes: This group of dyes has moderate substantivity to cellulose and requires moderate temperature for dyeing.

IN dyes: They have high substantivity to cellulose fibers. There is a high amount of caustic soda need for application without salt. This group dyes cellulose at high temperature [7-8].

Three IW (CI Vat Red 10, Vat Blue 66, Vat Yellow 46) and one IN (CI Vat Green 1) dyes were used in this study. Dyes were applied at % 0.5 and % 2 concentrations to achieve pale and medium/heavy depth of shades at 1: 20 liquor ratio. Pre-pigmentation method was carried out. Dyeing procedure and the amount of chemicals used are shown on Figure 2 and Table 1, respectively. Dyeing process was carried out with COPOWER SandoLab laboratory type exhaustion dyeing machine.

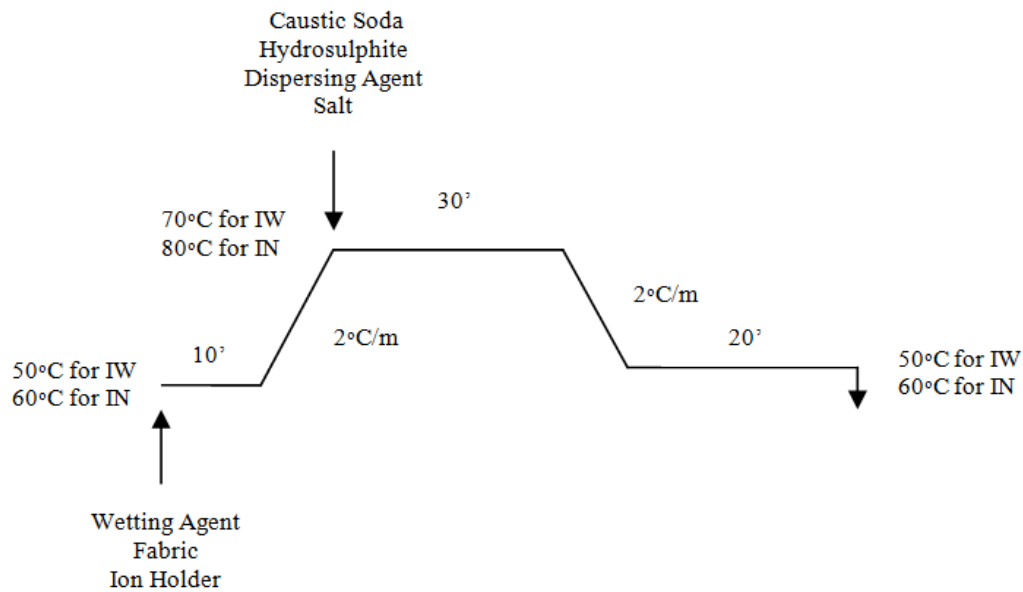


Figure 2: Dyeing procedure with vat dyes

Dye Type and Concentration	Caustic Soda (ml/l) (38°Be)	Hydrosulphite (g/l)	Salt (g/l)	Ion Holder (ml/l)	Wetting Agent (ml/l)	Dispersing Agent (ml/l)
IW %0.5	6	2.5	7.5	3	1	1
IW %2	7	3.5	12.5	3	1	1
IN %0.5	11	3.5	-	3	1	1
IN%2	13	4.5	-	3	1	1

Table 1: Chemical usage for vat dyeing of jute

Oxidizing process was carried out after dyeing. Dyed samples were reoxidized with 200 ml, 2ml/l H₂O₂ at 60°C for 15 minutes. Oxidized samples were firstly cold rinsed then washed at 90°C water. Samples were then washed with 1ml/l soaping agent and finally cold rinsed.

2.5. Color Measurements

Colors were measured by Datacolor 600 (D65 day light, 10° observer).

3. RESULTS AND DISCUSSION

3.1. Hydrophilicity

Hydrophilicity (wicking) test was carried out before and after enzyme treatment. 1 cm of sample bands with 3 cm width were soaked into potassium bi chromate solution then the heights of solution on the bands were measured at 10, 30, 60 and 90 seconds. The results are shown in Table 2.

Time (seconds)	Height of Solution on Sample Bands (mm)	
	Without Enzyme Treatment	With Enzyme Treatment
10	23	23
30	37	41
60	49	54
90	57	67

Table 2: Hydrophilicity of samples with and without enzyme treatment

The main aim of the pectinase treatment was to remove the non-cellulosic impurities, especially pectic materials. It is clear from Table 2 that the pectinase enzyme treatment improved the hydrophilicity of bleached jute samples. This might be due to the removal of the non-cellulosic impurities on bleached jute samples during the enzyme treatment.

3.2. Color Properties

Colorimetric data and color properties of vat dyed enzyme treated and non-treated jute fabrics are shown on Table 3, Figures 3-5.

Process Code	<i>K/S</i>	<i>L*</i>	<i>a*</i>	<i>b*</i>	<i>C*</i>	<i>h°</i>
0.5% Vat Red 10	3,4	55,01	37,93	8,10	38,79	12,05
Pectinase + 0.5% Vat Red 10	3	57,03	36,89	8,48	37,85	12,95
0.5% Vat Blue 66	2,9	51,06	-4,86	-22,47	22,99	257,79
Pectinase + 0.5% Vat Blue 66	2,9	50,99	-4,23	-22,91	23,30	259,53
0.5% Vat Yellow 46	4,1	80,77	-2,92	54,27	54,35	93,08
Pectinase + 0.5% Vat Yellow 46	3	82,87	-3,52	49,69	49,81	94,05
0.5% Vat Green 1	5,6	50,54	-34,09	-2,66	34,19	184,45
Pectinase + 0.5% Vat Green 1	4,2	53,73	-31,66	-2,60	31,77	184,69
2% Vat Red 10	12,8	39,34	44,02	11,94	45,61	15,17
Pectinase + 2% Vat Red 10	10,9	41,58	44,15	11,75	45,68	14,90
2% Vat Blue 66	10,3	34,02	-1,17	-27,39	27,41	267,54
Pectinase + 2% Vat Blue 66	9,4	35,08	-1,01	-27,52	27,54	267,89
2% Vat Yellow 46	13,5	74,93	2,60	74,72	74,77	88,01
Pectinase + 2% Vat Yellow 46	12,5	75,04	0,21	72,73	72,73	89,84
2% Vat Green 1	13,8	38,26	-34,62	-3,00	34,75	184,95
Pectinase + 2% Vat Green 1	13,5	38,25	-34,19	-2,85	34,31	184,77

Table 3: CIELAB Colorimetric Data of Vat Dyed Jute Samples

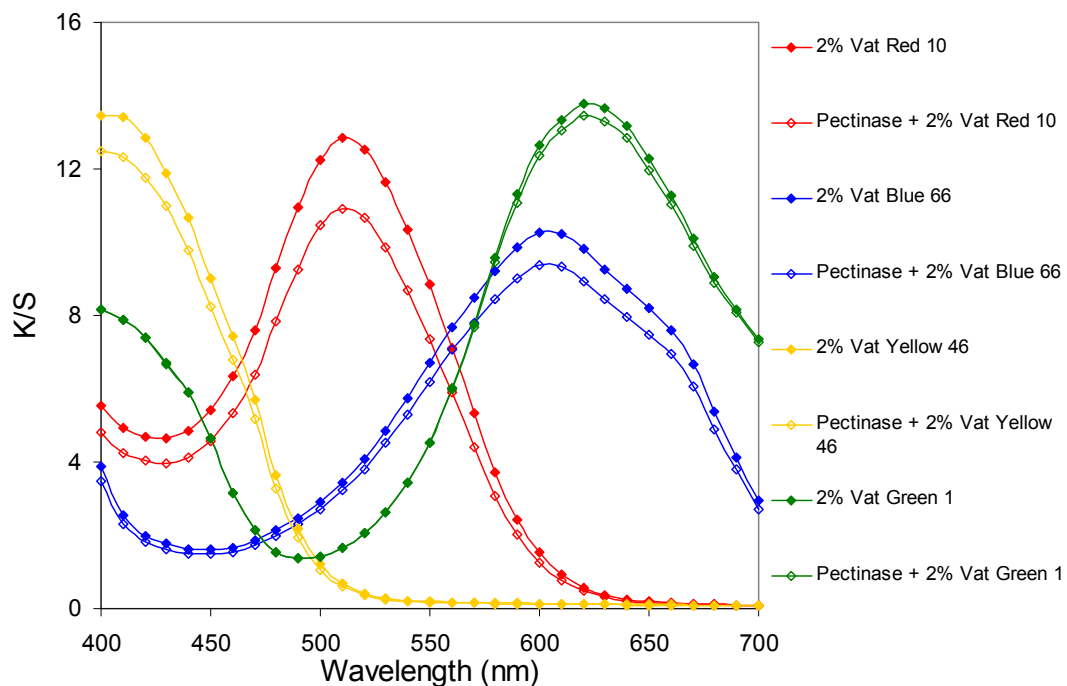


Figure 5: *K/S* spectra for 2% dyeing

Enzyme treated samples were more hydrophilic (Table 2), however; the enzyme treatment causes reduction on K/S values with the exception of 0.5% vat blue 66 dyeing. Moreover, darker shades were generally obtained without enzyme treatment with higher L^* values. The removal of non-cellulosic components with enzyme treatment may lead to this situation.

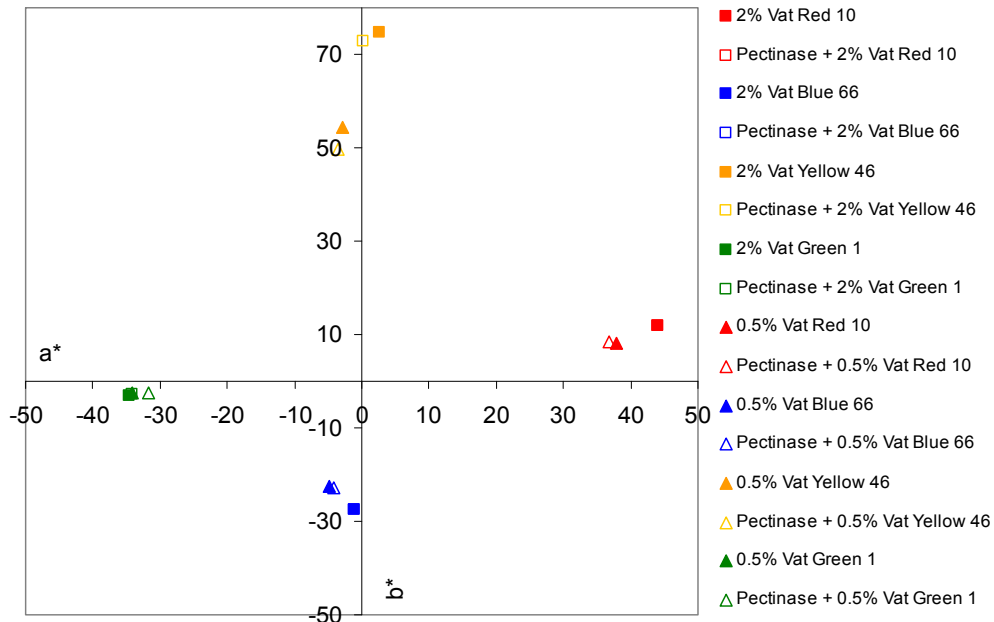


Figure 3: Locations of the Colors on a^*-b^* Plot

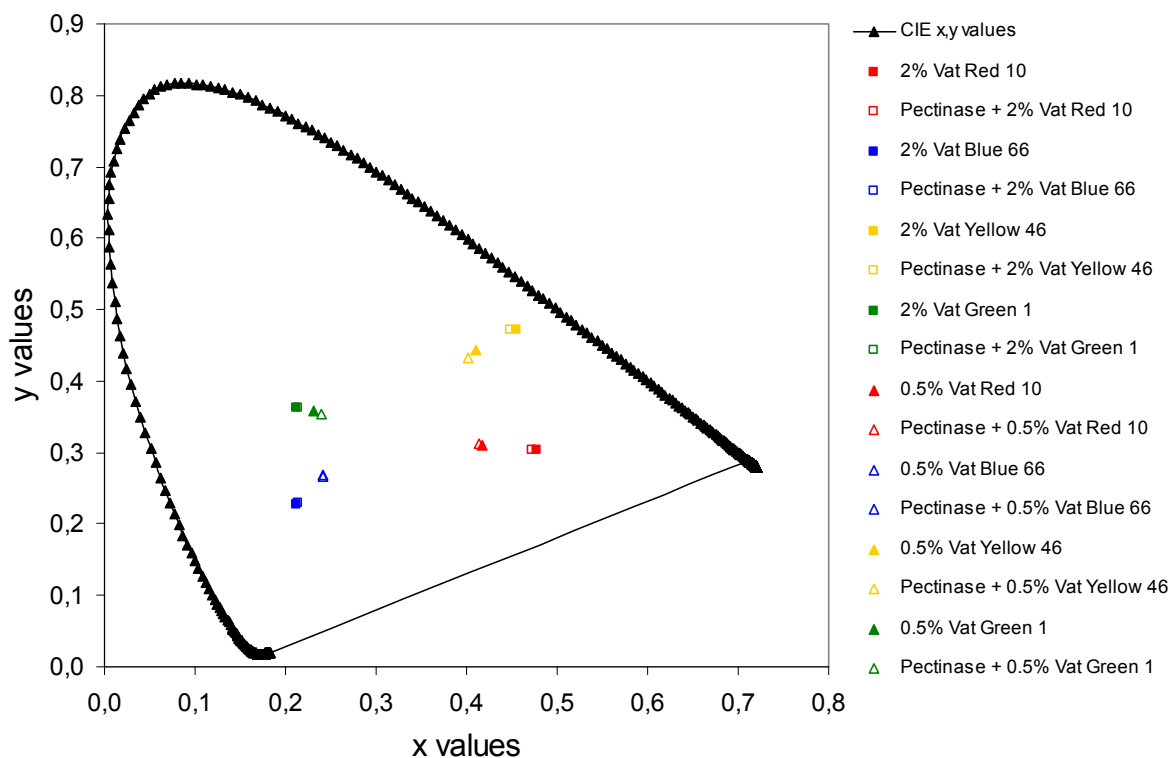


Figure 4: CIE chromaticity diagram of vat dyed jute samples.

CIE chromaticity diagram and a^*-b^* plot exhibits that the enzyme treatment generally caused very slight shade change for the same concentration of dyeing. This difference is clearer for the yellow shades (Figure 3).

3.2. Wash Fastness

Wash fastness properties are shown in Table 3.

Dyes	Wash Fastness Staining (C06-A2S)			
	Without Enzyme Treatment		With Enzyme Treatment	
	%0.5	%2	%0.5	%2
	Concentration	Concentration	Concentration	Concentration
Yellow	5	5	5	5
Red	5	5	5	5
Blue	5	5	5	5
Green	5	5	5	5

Table 3: Wash fastness properties

All samples showed excellent wash fastness values of 5 which was expected from vat dyes. Results exhibit that enzymatic treatment does not effect to wash fastness.

3.3. Rub Fastness

Rub fastness values are shown in Table 4.

Dyes	Rub Fastness (X12) (Cotton Staining)							
	Without Enzyme Treatment				With Enzyme Treatment			
	%0.5		%2		%0.5		%2	
	Concentration		Concentration		Concentration		Concentration	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Yellow	4/5-5	4/5	4/5-5	4-4/5	4	4	4	3/4
Red	5	4	5	3/4	4/5-5	4	4/5-5	3
Blue	4/5-5	4	4/5-5	3-3/4	4/5-5	4	4/5	3/4
Green	4/5-5	3/4	4/5	3	4/5-5	3	4/5-5	3

Table 4: Rub fastness values

Enzyme treatment generally has a negative effect on rub fastness of vat dyed jute fabrics. Enzyme treated jute fabrics exhibit up to 0.75 gray scale rating worse rub fastness values. Dry rub fastness results are commercially acceptable.

4. CONCLUSION

Although the pectinase enzyme treatment improved the hydrophilicity of bleached jute fiber, this treatment generally caused lower color yield and lower rub fastness properties. On the other hand, the enzyme treatment did not affect the wash fastness properties with 5 gray scale rating for all samples studied. It is known that higher color yield and better fastness values are important for choosing the right process. So for jute fiber, the pectinase enzyme treatment before vat dyeing does not lead to any advantage. Overall, commercially acceptable fastness results were achieved with vat dyeing of jute. Therefore, vat dyeing is a nice option for jute fibers for home textiles applications due to the high fastness requirements.

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COLOUR REMOVAL OF POLYAMIDE DYEING WASTEWATER WITH FE(III) AND CU(II) ACTIVATED HYDROGEN PEROXIDE

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Keywords: polyamide dyeing wastewater, acid dyes, colour removal, Fenton-like system

Abstract. *The colour in textile dyehouse effluent is a significant concern for the environment. The hues of the dyeing wastewater are aesthetically offensive, prone to interfere with the process of wastewaters disinfection and can affect the photosynthesis in receiving waters. One important advanced oxidation processes is the Fenton process, which uses hydrogen peroxide activated with bivalent iron salts to generate hydroxyl radicals. Besides Fe (II) salts, many other metallic catalyst systems have been tested. This study was undertaken to examine the feasibility of oxidative colour removal of wastewaters from polyamide dyeing with acid dyes, using two catalysts that are acrylic polyfunctional polymers chelated with metal ions (Cu(II) and Fe(III), respectively). It was found that the most effective of the two analysed catalysts is the Cu(II) based one, the Fe(III) based catalyst also providing fair results. Even if the first catalyst is recommended by its effectiveness, some difficulties are to be anticipated in connection with the difference between the pH value of the wastewater and the pH value required by the discoloration process.*

1 INTRODUCTION

The wastewater generated in the textile industry is characterized by significant levels of COD, dissolved and suspended solids, generally low level of BOD₅, and an intense colour¹. The colour in textile dyehouse effluent is a significant concern for the environment. The hues of the dyeing wastewater are aesthetically offensive, prone to interfere with the process of wastewaters disinfection and can affect the photosynthesis in receiving waters.

Conventional physicochemical or biological wastewater treatment methods are efficient in removing most of the pollutants in the textile wastewater, but are not effective for decolourization of textile wastewater. An alternative for the destructive elimination of the textile dyes is the chemical oxidation.

Advanced oxidation processes (AOPs), which are frequently used to treat wastewater of refractory pollutants, can also lead to high colour removal². Many AOP are based on the H₂O₂, because they offer high decolouration efficiency and besides that, H₂O₂ is considered to be a friendly oxidant since it decomposes into water and oxygen³.

One important advanced oxidation processes is the Fenton process, which uses hydrogen peroxide activated with bivalent iron salts to generate hydroxyl radicals⁴. Besides Fe (II) salts, many other metallic catalyst systems have been tested⁵.

This study was undertaken to examine the feasibility of oxidative colour removal of

wastewaters from polyamide dyeing with acid dyes, using two catalysts that are acrylic polyfunctional polymers chelated with metal ions (Cu(II) and Fe(III) respectively).

2 MATERIALS AND METHODS

Two anthraquinone acid dyes have been used: Acid Blue 80 and Acid Blue 40. Both dyes, that fall into the category of half milling dyes, were supplied by Bezema. The chemical structure of the dyes is shown in figures 1 and 2.

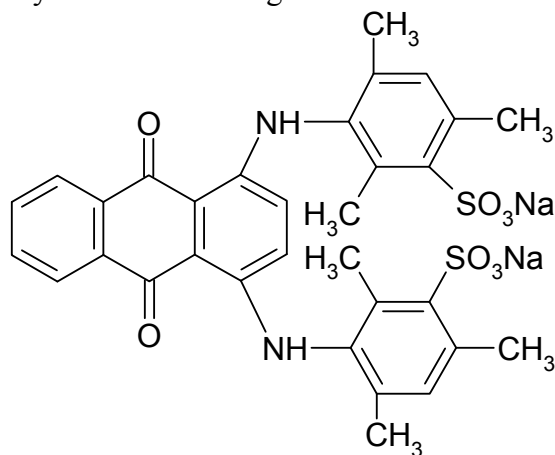


Figure 1. Chemical structure of Acid Blue 80

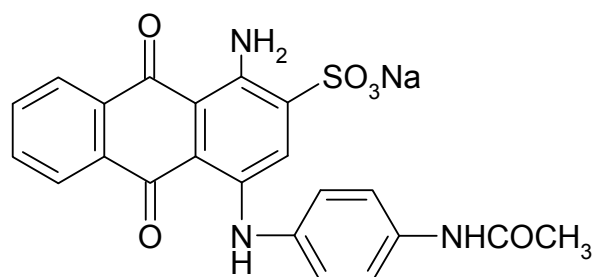


Figure 2. Chemical structure of Acid Blue 40

The dyes and all the used reagents were commercially obtained and used without further purification.

Polyamide fabrics weighing 130 g per meter were dyed to determine the exhaustion. The value of the exhaustion was determined by spectroscopic analysis of the dye bath before and after dyeing at different times, using formula (1). For each dye a calibration curve was determined by measuring the absorbance of the dye solutions of known concentration. The calibration curves for both dyes had $r^2 > 0.99$.

$$E, \% = \frac{c_o - c_f}{c_o} \times 100 \quad (1)$$

where:

E - the degree of dye exhaustion from the dyebath, as percentage,

c_o - the concentration of the dye before the dyeing process;

c_f - the concentration of the dye after the dyeing process⁶

For the discoloration of wastewaters, hydrogen peroxide solution (Merck, 30% w/w) has been used. To activate the hydrogen peroxide decomposition, we have used catalysts from resins functionalized with amines and saturated with Fe(III) and Cu (II), respectively. The colour removal degree, expressed as percentage, had been calculated

from the relative decrease of absorbance, according to the formula (2), where Abs_0 is the absorbance of the initial solution and Abs_f is the absorbance of the final solution.

$$\% \text{ Colour Removal} = \left(\left(1 - \left(\frac{Abs_f}{Abs_0} \right) \right) * 100 \right) \quad (2)$$

All absorbance measurements were made by a UV/VIS Camspec M501 spectrophotometer, at maximum absorbance wavelength (626 nm for Acid Blue 80 and 610 nm for Acid Blue 40).

The pH values were detected by a COLE PARMER pH/mV meter.

3 EXPERIMENTAL

Dye exhaustion is a significant dyeing parameter relative to the pollution degree, because it indicates to which extent the effluent is polluted with dye.

Polyamide fabrics samples were dyed with 3.00% owf acid dye and a liquor-to-goods ratio of 20:1. The pH used was 4 adjusted by acetic acid.

The dyeing was performed in an Ahiba lab dyeing machine, starting at room temperature, and then increased to the water boiling temperature, and held for 80 min. After the dyeing process, samples were thoroughly rinsed with cold tap water until no colour bleeding was noticed.

To analyse the colour removal process using hydrogen peroxide in the presence of Fe(III) and Cu(II) based Fenton-like catalyst synthetic wastewater has been used.

In order to prepare the synthetic wastewater, 1250 mg of sodium sulphate and the appropriate quantity of acid dye were dissolved in 500 mL of distilled water in a 1dm³ Erlenmeyer.

Previous research showed that best colour removing efficiency is reached at pH=2 for the Fe(III) based catalyst and pH=9 for the Cu(II) based catalyst^{7,8}. The pH was adjusted to the required value with H₂SO₄ and NaOH, respectively.

The discoloration experiments were carried out according to the methodology that proved to offer optimal results in previous studies: 0,5 mL hydrogen peroxide 30%, activated with 0,06 g catalyst, have been added to 50 mL of wastewater samples (adjusted with H₂SO₄ to pH 2 for Fe(III) based catalyst and to pH 9 with NaOH for the Cu(II) based catalyst) and the treatment continued for 60 minutes⁹. Three treatment temperatures have been tested: 20°C, 50°C and 98°C. The dye concentration ranged between 40 and 180 mg/L, and the electrolyte concentration (sodium sulphate) was 2,5 g/L in all cases.

4 RESULTS AND DISCUSSION

Percentage exhaustion values of two acid dyes at different dyeing times are shown in figure 3. It can be seen that after 80 minutes of treatment at boiling temperature, the value of the exhaustion is slightly over 90% (92% for Acid Blue 40 and 91 % for Acid Blue 40). That means that when dyeing with 1% dye owf at a liquor-to-goods ratio of 20:1, it is to expect a 50 mg/L dye concentration in the resulting wastewater. Taking into consideration the possibility of darker hues and different liquor-to-goods ratio values, it was assumed that the range of concentrations for the residual dye in wastewater is between 40 and 180 mg/L, and this interval of values was analysed later on in this study. A similar calculation leads to the conclusion that the concentration of electrolyte (sodium sulphate) in the wastewater is around 2,5 g/L (when the initial concentration of the electrolyte is 5% owf).

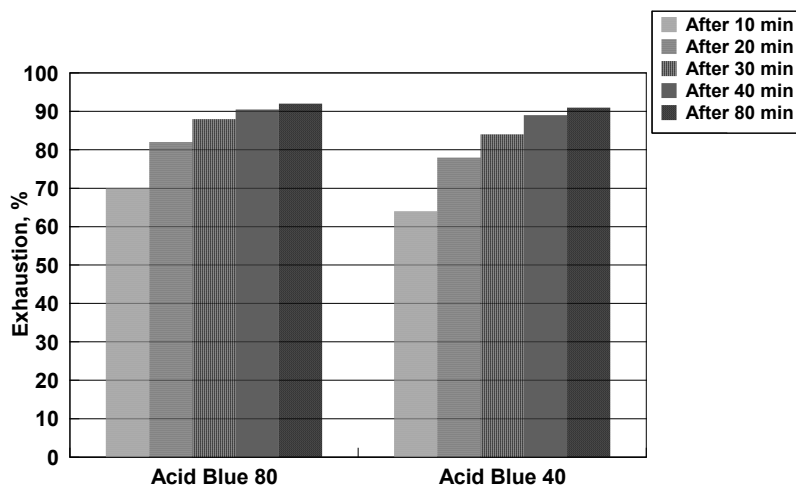


Figure 3. Percentage exhaustion values for the two acid dyes

The variation of the colour removal of the Acid Blue 80 (concentration 110 mg/L) with the treatment time at three temperatures is presented in figures 4 and 5.

Figure 4 shows the efficiency of the colour removal process when using the Fe(III) based catalyst. It can be seen that the temperature of the treatment plays a very significant role. Both colour removal values and the velocity of the process are highly influenced by the temperature. At room temperature the process is slow and ineffective (only 28% colour removal after 60 minutes). An increase in temperature (50°C) leads to better discoloration, but only after more than 1 hour of treatment. Only close to the boiling temperature the process is efficient and fast. In only 10 minutes the colour is almost completely removed (colour removal 98%).

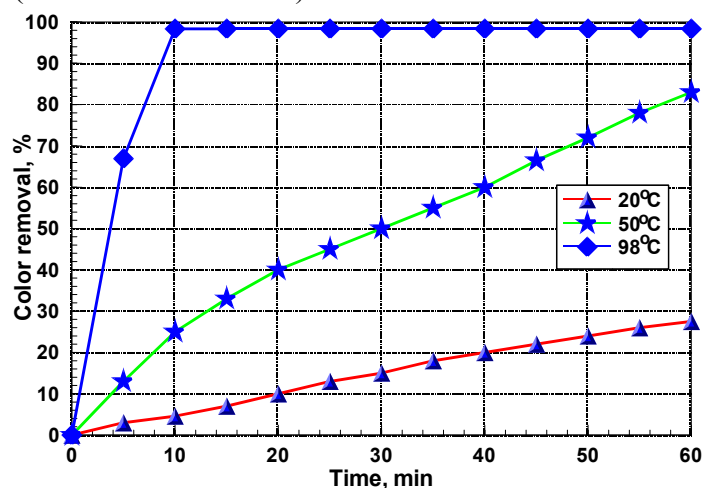


Figure 4. Variation in time of the colour removal of Acid Blue 80, 110 mg/L, Fe(III) based catalyst, 2,5 g/L electrolyte, at three treatment temperatures

The results obtained for the same dye when using the Cu(II) based catalyst are shown in figure 5. It can be seen there are many similarities with previous colour removal process, but there are some significant differences. It can be still observed an important temperature dependence of the process, and at room temperature smallest colour removal values are obtained. The highest colour removal is slightly lower with this catalyst (96%, while in the case of the Fe(III) catalyst 98% colour removal was obtained), but even at 20°C the final colour removal is significantly higher (63% after 1 hour of treatment).

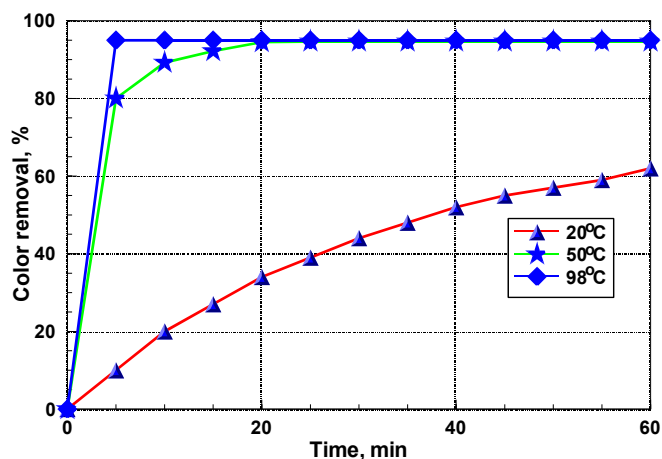


Figure 5. Variation in time of the colour removal of Acid Blue 80, 110 mg/L, Cu(II) based catalyst, 2,5 g/L electrolyte, at three treatment temperatures

What is more important, at 50°C the maximum colour removal (96%) is reached after only 20 minutes. It can be concluded that the Cu(II) based catalyst gives better overall result, as very high colour removal is obtained at a very convenient treatment temperature (50°C), after less than half an hour.

Figures 6 and 7 show the variation of the colour removal of the Acid Blue 40 solution (concentration 110 mg/L) with the treatment time at three temperatures.

When the Fe(III) catalyst is used, the results are very good at boiling temperature (98%) after only 15 minutes of treatment. For inferior treatment temperatures, both the efficiency of the treatment and the velocity of the discoloration process are low (especially at room temperature, when after 1 hour of treatment only a colour removal of 38% is reached).

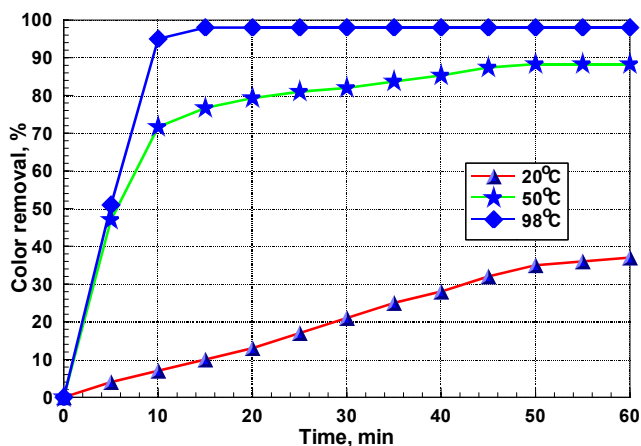


Figure 6. Variation in time of the colour removal of Acid Blue 40, 110 mg/L, Fe(III) based catalyst, 2,5 g/L electrolyte, at three treatment temperatures

Better results are obtained when using the Cu(II) catalyst. Compared to the Fe(III)-based catalyst, even at room temperature, a double value of the colour removal is obtained after 1 hour, and the velocity of the discoloration process at 50°C is significantly higher. The maximal value of the colour removal (98%) is reached after only 15 minutes; for the 98°C treatment the colour removal is almost instantaneous. Considerably high colour removal values were obtained at room temperature after 2 hours of treatment (86%).

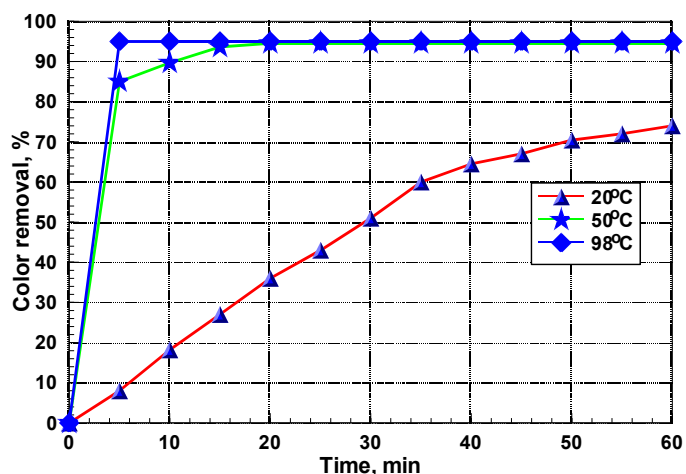


Figure 7. Variation in time of the colour removal of Acid Blue 40, 110 mg/L, Cu(II) based catalyst, 2,5 g/L electrolyte, at three treatment temperatures

In order to analyse the influence of the dye concentration, three dye concentrations have been tested (40 mg/L, 110 mg/L and 180 mg/L), using the catalyst that proved to be more efficient (the Cu(II) based one), at 50°C treatment temperature and the same treatment parameters. The results obtained for Acid Blue 80 are shown in figure 8.

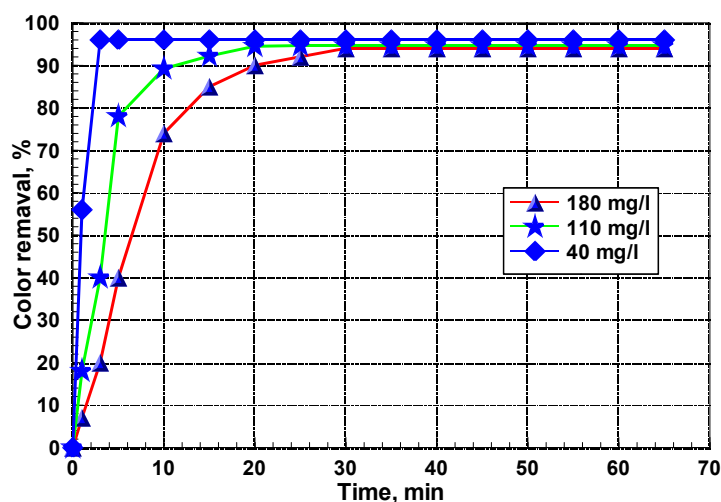


Figure 8. Variation in time of Acid Blue 80 colour removal, Cu(II) based catalyst, 2,5 g/L electrolyte, 50°C treatment temperature, at three dye concentrations

From Figure 8, high colour removal under the specified conditions can be observed; even for large dye concentrations, such as 180 mg/L, 30 minutes of treatment are sufficient to obtain an advanced discoloration (over 95%).

A similar behaviour can be noticed for Acid Blue 40 (figure 9); the only difference is that at least 35 minutes of treatment in the indicated conditions are needed to achieve the maximum colour removal effect.

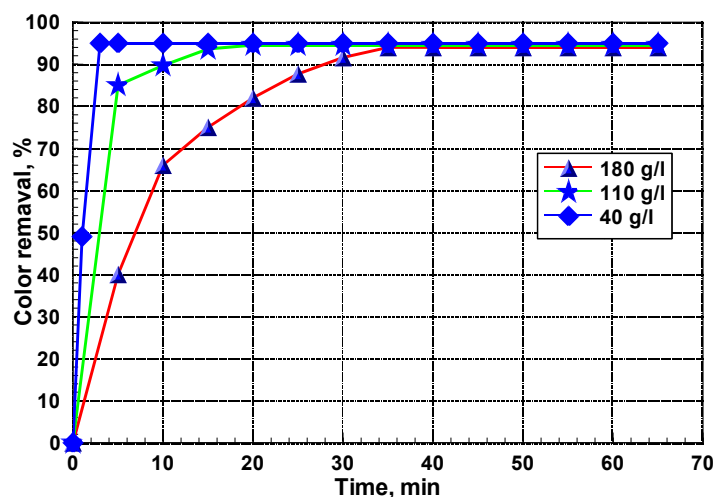


Figure 9. Variation in time of Acid Blue 40 colour removal, Cu(II) based catalyst, 2,5 g/L electrolyte, 50°C treatment temperature, at three dye concentrations

The influence of electrolyte concentration was analysed by treating solutions of 50 mg/L dye with two electrolyte concentrations at a temperature of 50°C, using the catalyst which recorded the best results in previous tests (the Cu(II) based catalyst). The results are presented in the following figures.

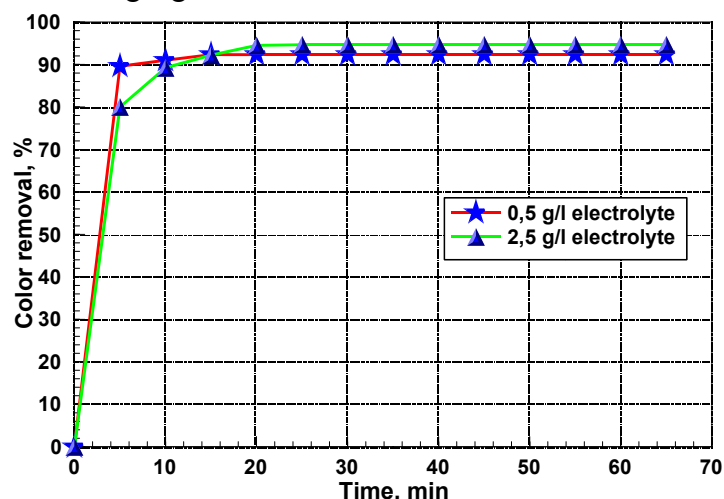


Figure 10. Influence of electrolyte concentration on the colour removal of 50 mg/L Acid Blue 80 solution, Cu(II) based catalyst, 50°C treatment temperature

In the case of Acid Blue 80, both the low electrolyte concentration of 0.5 g/L, as well as the higher electrolyte concentration of 2.5 g/L lead to very high degrees of colour removal (discoloration is almost total); anyway, the colour removal is very slightly affected by the higher electrolyte concentration (95 % compared to 92 % after 20 minutes of treatment).

Influence of electrolyte on Acid Blue 40 discoloration behaviour is shown in Figure 11. This time the influence of electrolyte concentration is also unimportant; it is virtually zero in terms of the final colour removal and very low in terms of process velocity (15 minutes to reach the maximum colour removal for the 0,5 g/L electrolyte concentration and less than 20 minutes for 2,5 g/L electrolyte concentration).

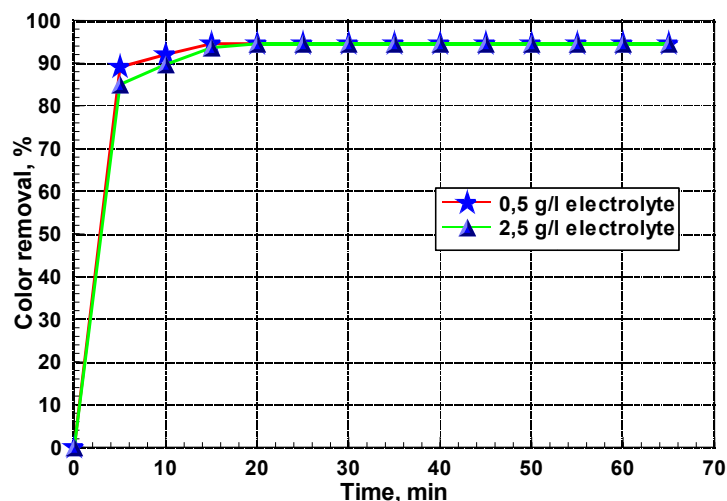


Figure 11. Influence of electrolyte concentration on the colour removal of 50 mg/L Acid Blue 40 solution, Cu(II) based catalyst, 50°C treatment temperature

To study the behaviour of dye mixtures, the discolouration capacity of a solution containing a global concentration of 50 mg/L dye, namely 25 mg/L Acid Blue 80 and 25 mg/L Acid Blue 40, electrolyte concentration 2,5 g/L, was analysed.

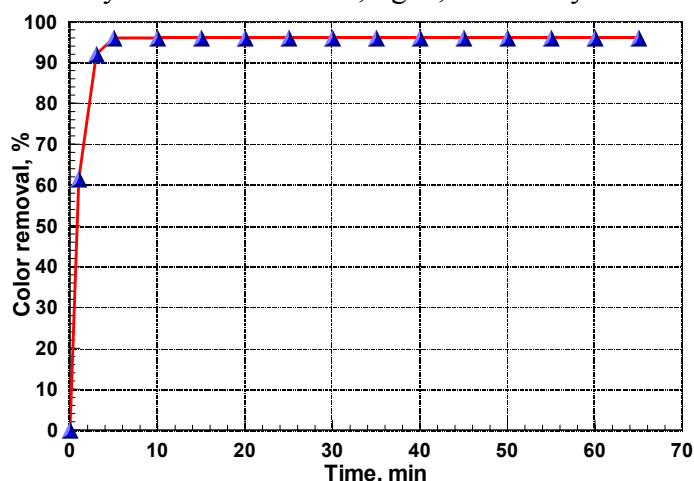


Figure 12. Variation in time of the colour removal of mixture of dyes (25 mg/L Acid Blue 80 and 25 mg/L Acid Blue 40), Cu(II) based catalyst, 2,5 g/L electrolyte, 50°C treatment temperature

It can be noted that the presence of the two dyes does not result in adverse effects on the effectiveness of the colour removal process.

5 CONCLUSIONS

From the two analysed catalysts, the Cu(II) based one is the most effective, the Fe(III) based catalyst also providing fair results. Even if the first catalyst is recommended by its effectiveness, some difficulties are to be anticipated in connection with the difference between the pH value of the wastewater and the pH value required by the Cu(II) based catalyst.

For the first studied acid dye, Acid Blue 80, the Cu-based catalyst provided a very advanced colour removal even under treatment at 50°C, and therefore it is advisable to be used for discolouration, even if a significant pH correction is necessary.

Acid Blue 40 is efficiently discoloured when using the Fe (III)-based catalyst, even at 50°C, after one hour of treatment. Still, the obtained colour removal is lower than that

obtained at 98°C (88% vs. 98%). Moreover, the velocity of the discoloration process differs significantly (about 15 minutes at 98°C to achieve the maximum degree of discoloration and 50 minutes to obtain the same colour removal at 50°C). In contrast, when using the Cu(II)-based catalyst at 50°C, the discoloration is very fast (less than 20 minutes) and complete.

The study of the influence of dye concentration on the efficiency of discoloration demonstrated that the Cu(II)-based catalyst process is efficient for a wide range of concentrations.

It was concluded that the effect of the electrolyte concentration on the efficacy of the colour removal is virtually nil in terms of effectiveness of the discoloration, but the rate of the process is slightly influenced by it.

ACKNOWLEDGEMENTS

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NATURAL ANTIBACTERIAL FINISHING OF WOOL FIBER USING PLASMA TECHNOLOGY

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Keywords: Wool, Mordant, Plasma, Dyeing, Natural Dye, Antibacterial

Abstract: *In this study, Berberine, a natural cationic dye extracted from the roots and woods of Berberis Vulgaris, was used to dye wool fibers. To improve the dyeability of the fibers and reduce the dyeing temperature, an environmental friendly pretreatment, low temperature plasma treatment, was performed. Atmospheric air was used as plasma treatment gas. The effect of plasma treatment and Mordanting on dyeing and fastness properties of wool fiber was studied. Plasma treatment improved the absorption of the cationic dye to wool fiber. Compared to untreated samples, plasma treated wool showed better dyeability with good fastness properties against washing, rubbing and light. Also, pre-mordanting with Alum improved the fastness properties of dyed samples. The dyed samples were tested for antibacterial activity against two gram negative and gram positive bacteria, using AATCC test method 100-2004. The dyed wool represented a high level of antibacterial activity.*

1. INTRODUCTION

In the field of textiles and the cosmetics industry natural dyes have been gaining interest particularly with respect to growing awareness of environmental and health-related problems [1]. Compared with Synthetic dyes, they have several advantages such as biodegradability, non toxic functions, specific medical actions and environmentally friendly finishes [2]. Natural dyes can be derived from almost anything—plants, minerals, and even some insects. Most natural dye colors are found in the roots, bark, leaves, flowers, skins, and shells of plants [3]. Some natural dyes, when applied on textiles, show antibacterial effects, so can be considered as functional dyes with health care properties. Natural dyes extracted from Henna [4], Amur cork tree [5-6], *Rhizoma coptidis* [7], Citrus grandis Osbeck [8] and *Berberis vulgaris* [2] have shown considerable antibacterial effect when applied on textile fibers.

The surface of a wool fiber plays a critical role in wool processing, particularly with respect to dye uptake. Wool fiber surface is of a protein matrix heavily acylated with lipid, predominantly 18-methyleicosanoic acid. Removal of the lipid layer results in improvement in polymer adhesion and dye uptake [9].

Ecologic and economic restrictions which are increasingly imposed on the textiles industry require the development of environment friendly and economic processes. Plasma treatment is a promising approach for surface modification of textiles without affecting the bulk properties. The effect of plasma treatments in wool dyeing has been studied [10]. Corona treatment uses ionized air to modify the surface of the wool fibers. The presence of high amounts of oxygen and nitrogen species in the plasma gas induces chemical and physical changes on the surface through oxidation, grafting and adhesion, by the formation of

carbonyl, carboxylic, hydroxyl, amino, nitro, etc. groups [11]. Plasma treated wool fabrics have shown better dyeability with acid [11], reactive and metal complex [12] dyes. In this study, we have studied the effect of atmospheric pressure plasma treatment on dyeability of wool fiber with a cationic natural dye. The antibacterial activity of dyed fabric has been evaluated too.

2. MATERIALS AND METHODS

2.1 Materials

In this work, plain woven wool fabric (250 g/m²) was supplied from Iranmerinos textile Company, Iran. Before being used, the fabric was scoured with a solution containing 1 g/L non-ionic detergent at 45 °C for 20 minutes. Then the fabric was thoroughly washed with water and air dried at room temperature.

Berberis vulgaris roots were first washed and dried and then powdered. To prepare the original solution of the dye, each 100 gram of powder was added to 1 liter of distilled water and boiled for 2 hours and then filtered. The concentration of the resultant solution is 10% W/V. All chemicals used were analytical grade reagents from Merck.

2.2 Methods

Plasma treatment: The samples were treated in an atmospheric pressure plasma chamber composed of two parallel electrodes with 3 mm space. The samples were placed between the electrodes. In all treatments, air was used as the processing gas with the power of 50 watts, voltage of 20 KV and frequency of 10 KHz at different time intervals.

Mordanting: The scoured wool fabrics were mordanted using 2% owf of alum (aluminium potassium sulfate) at 80 °c and L:G= 40:1, for 45 minutes.

Dyeing: 100 cc of original dye solution was mixed with 100 cc of distilled water for each 5 gram of wool (L:G= 40:1). To maximize the absorption of berberin cationic dye to wool fiber, pH of the dyebath was adjusted on 8 (according the author's previous study [2]) using sodium carbonate. The dyeing was started at 40°c and the temperature was raised to final temperature (60, 70, 80, 90 and 100 °c) at the rate of 2°c per minute. Then the samples remained in that condition for appropriate time (30, 45, 60, 90 minute), and then rinsed and air dried. All mordanting and dyeing processes were carried out using a laboratory dyeing machine made by Rissanj co.-Iran.

Color measurements: the reflectance of dyed samples and color coordinates CIE L*, a*, b* values were measured on a Color-eye 7000A spectrophotometer using illuminant D65 and 10°standard observer. Color strength (K/S) of dyed samples were calculated using Kubelka-munk equation:

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

Where R is the observed reflectance, K is the absorption coefficient and S is the light scattering coefficient.

Color fastness tests: color fastness to washing, light and rubbing was measured according to: ISO 105-C01: 1989(E), ISO 105-B02: 1994(E), ISO 105-X12: 1993(E), respectively.

Antibacterial test: the antibacterial property of dyed samples was quantitatively evaluated according to AATCC 100-2004. the bacterial species used were: *Klebsiella pneumoniae* (Gram negative) and *Staphylococcus aureus* (Gram positive). The colonies of both bacteria before and after incubation on the agar plate were counted by microscope. The reduction in the number of bacteria which was calculated using equation 2 shows the efficacy of the antibacterial treatment.

$$E\% = [(N1-N2)/N1] * 100 \quad (2)$$

Where N1 is the number of bacteria colonies at the beginning of the test (0 hour), and N2 is the number of bacteria colonies after 24 hours contact of dyed samples.

SEM images was taken using (*****) to study the effect of plasma treatment on the surface structure of wool fibers.

3. RESULTS AND DISCUSSION

3.1 Effect of plasma treatment on color strength of dyed wool

Figure 1 shows the effect of plasma treatment time on the color strength of wool sample dyed for 45 min at 60 °c. It is evident that plasma treatment increased the absorption of the cationic dye to wool fiber and the color strength increases with increase in plasma treatment time up to 3 minutes.

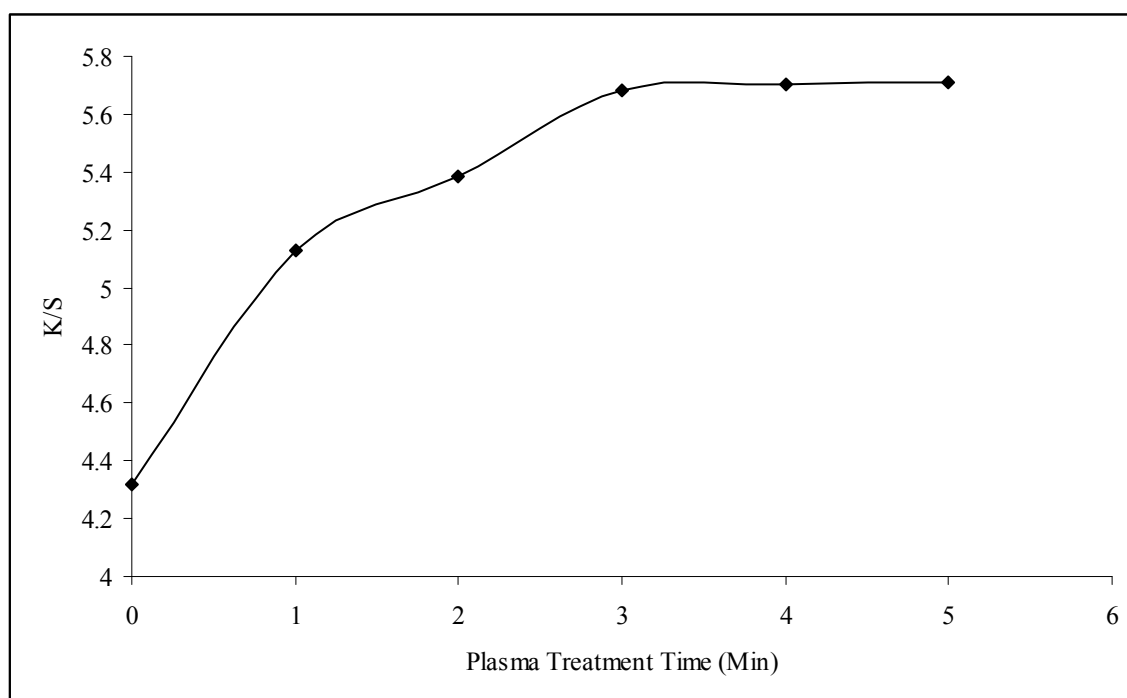


Figure 1: Effect of plasma treatment time on color strength of samples dyed for 45 min at 60 °c

It can be seen from figure 2 that the plasma treated samples show higher color strengths than untreated wool, when dyed at 60 °c for the same time. The color strength of untreated sample dyed for 60 min is equivalent to the plasma treated one dyed for 45 min. Figure 3 shows the effect of dyeing temperature on color strength of untreated and plasma treated wool. The color strength rises with increase in temperature for both samples, but it is greater for plasma treated sample when dyed at the same temperature. The color strength of plasma treated sample dyed at 70 °c is equivalent to that of untreated one dyed at 100 °c. It can be deduced from figures 2 and 3 that compared to untreated wool; plasma treatment can lower the dyeing time and temperature when the same color strength is desired. This is important from both economical and ecological point of view.

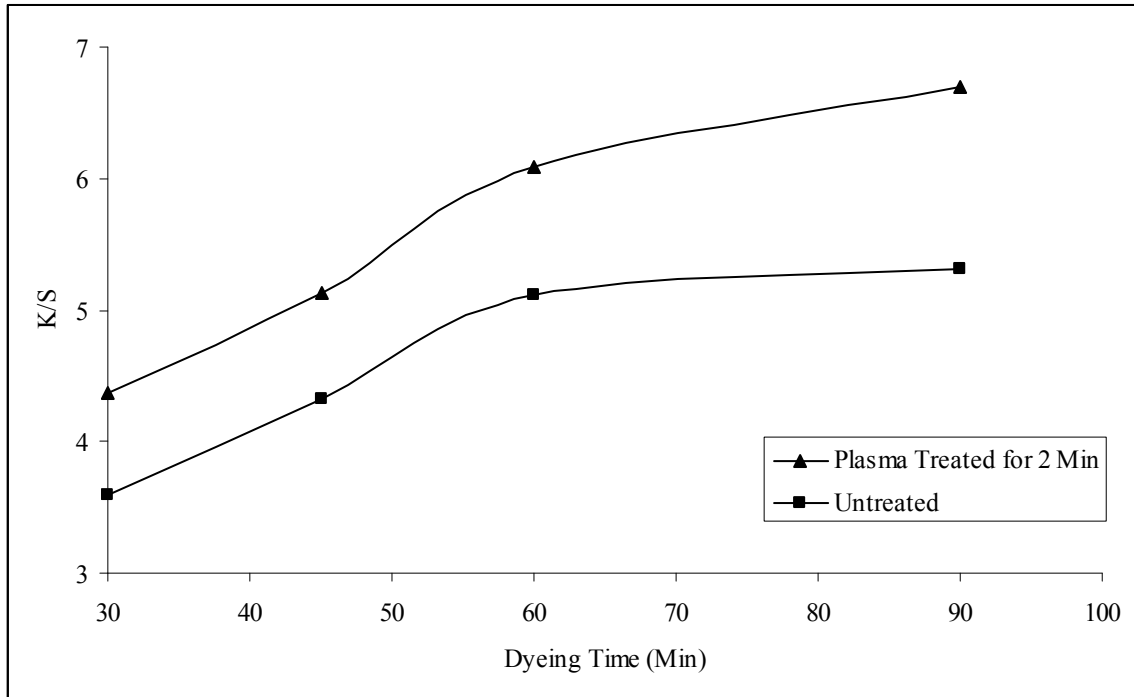


Figure 2: Effect of dyeing time on color strength of samples dyed at 60 °c

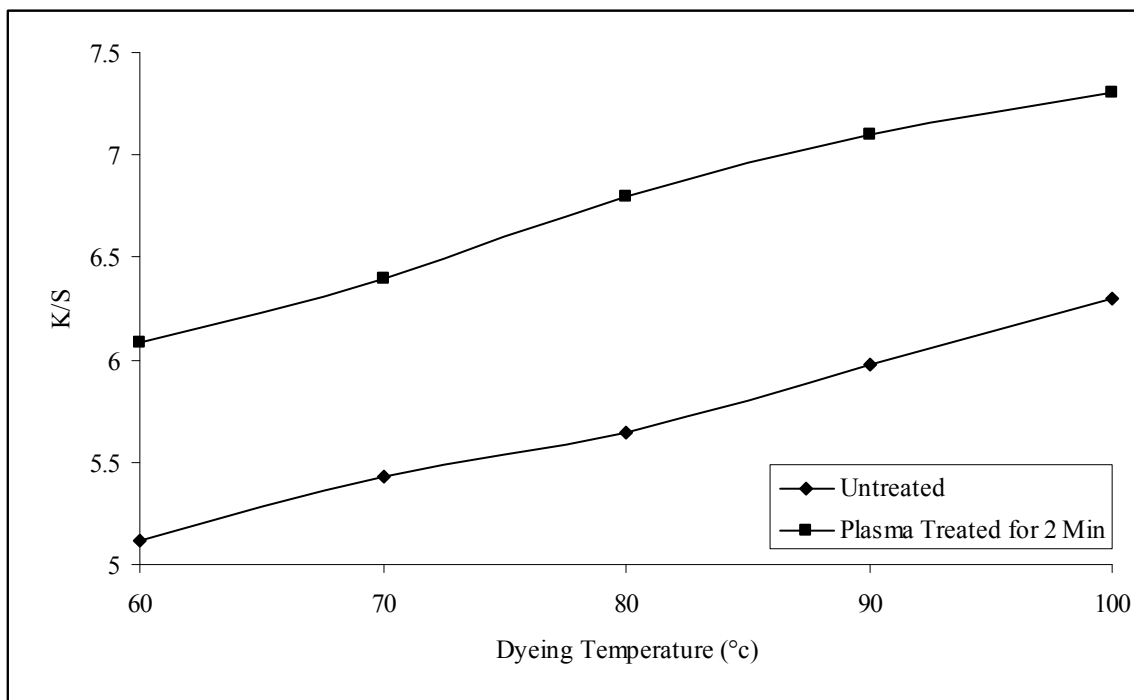


Figure 3: The effect of dyeing temp. on color strength of untreated and plasma treated wool dyed for 45 Min.

3.2 Effect of mordant on dye absorption

According to table 1, pre-mordanting with 2% owf alum increased the color strength of both untreated and plasma treated samples when dyed. Also, the L^* of untreated sample is higher than plasma treated one, which confirms the higher dye absorption on plasma treated wool when pre-mordanting is performed. Aluminum mordant absorbed onto the wool fiber increased its dyeability with Berberine dye.

	K/S	L*
Untreated - Unmordanted	5.12	70.35
Untreated - Mordanted	5.35	69.12
Plasma Treated - Unmordanted	6.08	68.43
Plasma Treated - Mordanted	6.42	67.05

Table 1: Effect of mordanting with 2% owf alum on dyeability of untreated and plasma treated wool (45 min at 60 °c)

3.3 Fastness properties

Table 2 shows the fastness properties of untreated and plasma treated (mordanted and unmordanted) dyed wool. There is no difference between fastness properties of untreated and plasma treated wool. All fastness properties of dyed samples when mordanted are higher than when unmordanted. This increase is due to increase in size of dye molecules when connected to metal atoms into the fiber. Wet rub fastness was less than dry rub fastness because the water molecules can dissolve some of water-soluble dye molecules and make them easier to be removed from the fiber by rubbing. All fastness properties of plasma treated, mordanted and then dyed wool fibers are generally acceptable.

	Wash Fastness	Rub Fastness (dry)	Rub Fastness (wet)	Light Fastness
Untreated - Unmordanted	3-4	4	2-3	5-6
Untreated - Mordanted	5	4-5	3-4	5-6
Plasma Treated - Unmordanted	3	4	2	6
Plasma Treated - Mordanted	3-4	4-5	3-4	6

Table 2: Fastness properties of untreated and plasma treated (2% owf alum mordanted and unmordanted) dyed wool

3.4 Surface analysis

According to figure 4, plasma treatment for 2 min destroyed the surface layer (scales) of wool fiber. This can lead to increase in dye penetration into the fiber and lower the dyeing time and temperature compared to untreated samples.

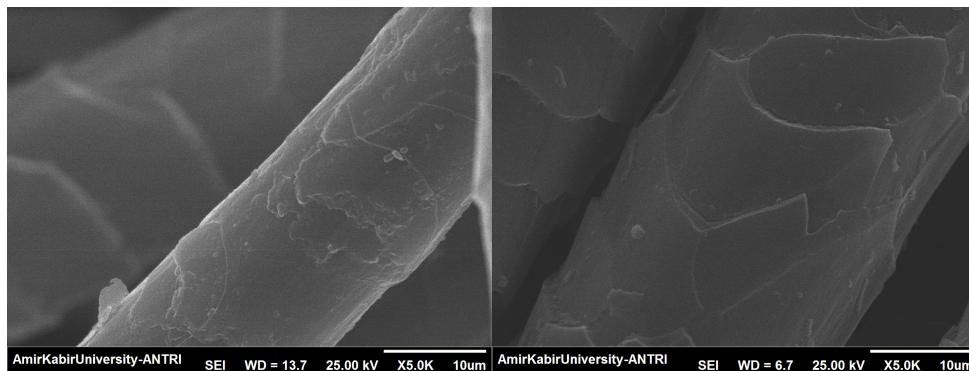


Figure 4: SEM images of untreated and plasma treated wool (2 min)

3.5 Antibacterial activity

Table 3 shows the percent reduction in number of two bacteria after 24 hours incubation on the surface of undyed and dyed (after 2 min plasma treatment) wool. It is obvious that the dyed wool has excellent antibacterial activity against both bacteria used in this study. Berberine colorant is a quaternary ammonium compound, containing a positive charge on N atom that could destroy the negatively charged cell membrane of the bacteria by disturbing charge balances of cell membrane. Other detrimental effects of quaternary ammonium compounds on microbes are the denaturizing of proteins and the disruption of the cell structure [2].

Sample	Bacteria	<i>Staphylococcus aureus</i>	<i>Klebsiella pneumoniae</i>
	Control (Undyed)	0 %	0 %
	Plasma treated - Alum mordanted - Dyed	99.5 %	99.6 %

Table 3: Antibacterial activity of different samples (% reduction of bacteria after 24 hr incubation)

4. CONCLUSION

Beberine, which is a cationic colorant present in the extract of *berberis vulgaris* root can be used as a natural dye for wool. Mordanting with aluminum before dyeing increased the dye uptake and fastness properties of the samples. Wool fiber dyed with this dye has great antibacterial activity against both gram positive and gram negative bacteria. Atmospheric air plasma treatment can enhance absorption of this dye into wool fiber. This environmentally friendly pretreatment can lower the needed time and temperature for wool dyeing. Furthermore, this process is environmentally friendly and has the minimum pollution. This natural dye can be used for dyeing wool with good fastness and excellent antibacterial properties.

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STUDY PROCEDURES FOR FINISHING TEXTILE MATERIALS WITH PCM CONTENT

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Keywords: man-made cellulosic fibers, PCM, thermoregulatory properties, finishing procedures, heat of fusion, physical-chemical-mechanical characteristics

Abstract: *For the finishing of textile materials containing phase change materials (PCMs) with thermoregulatory properties of the human body, a great importance should be given to each operation that occurs in the technologic flow of the finishing process, so that the PCMs from the fiber's structure would not be eliminated by preliminary treatments, dyeing or by the final finishing applied procedures. Through experiments carried out on laboratory equipment, the influence of chemical auxiliaries used in the preliminary process, as well as of the applied technological parameters (temperature, pH and treatment duration) on the heat of fusion of textile materials made of cellulosic man-made fibers containing PCM, were analyzed. Various methods of preliminary treatment followed by dyeing were applied to enable the complex physical-mechanical investigation of the man-made cellulosic materials with PCM content. The technical and qualitative performances of the applied dyeing processes and the dyeability of the textile materials containing PCMs have been assessed. Thermal properties (heat of fusion and melting peak) were measured.*

1. INTRODUCTION

The Integration of PCMs in clothes is a straightforward method to obtain the desired thermo-regulating properties. When body temperature increases, the PCM melts and absorbs heat from the body. Then, when the temperature drops, the PCM solidifies and the stored heat is released again and thus it has the ability to stabilize the body temperature. The process of melting or solidification takes place at a constant temperature until the whole material is melted or solidified. This behavior of PCM is the basis for its temperature regulating effect as a component in textile fibers [1].

In this paper, the influence of finishing operation on knitted fabric with SmartcelTM clima fibers content was studied. SmartcelTM clima fiber is the newest fiber with thermo regulating features of Smartfiber AG (Germany), developed by a new concept for incorporating PCMs in wet spun cellulose fibers based on direct addition of free PCM to a cellulose solution [2].

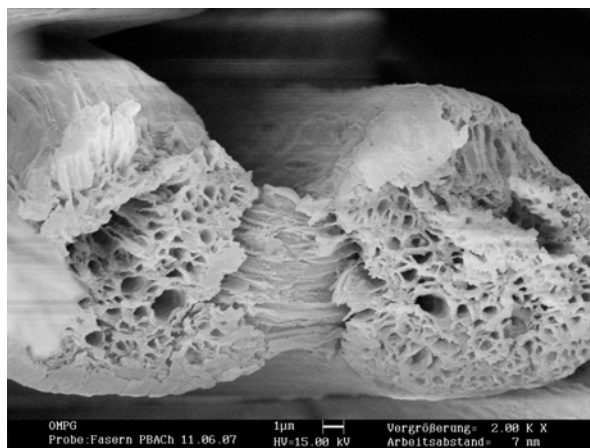


Figure 1: SEM picture of a Lyocell fibre with direct incorporated PCM-paraffin

2. EXPERIMENTAL PART

2.1 Textile materials used

Knitted fabrics made of fiber blends of 70% cotton / 30% Smartcel™ clima fibers were used in this study.

2.2 Finishing procedures

Various methods of preliminary treatment and dyeing were applied, on piece laboratory dyeing apparatus “Redkrome” (Ugolini-Italy) at a bath ratio of 1:10, as follows:

- **sample code V₁'**: a strong alkaline treatment (at temperature of 98°C, duration of 60 min, in the presence of 8 mL/L NaOH 38°Bé, Na₂CO₃, Na₃PO₄, a nonionic surfactant and a sequestering agent of Ca-Mg-Fe ions), followed by bleaching in subsequent phase (at temperature of 98°C, duration of 60 min, in the presence of a nonionic surfactant, a H₂O₂ stabilizer, a sequestering-dispersing-colloid protector agent, 4 mL/L NaOH 38°Be and 15 mL/L H₂O₂ 30%), followed by dyeing with a bi-functional reactive dyestuff and drying (different temperature and duration);
- **sample code S₁'**: a mild alkaline treatment (at temperature of 98°C, duration of 45 min, in the presence Na₂CO₃, a nonionic surfactant and a sequestering agent of Ca-Mg-Fe ions, without the using of NaOH), followed by bleaching in subsequent phase (at temperature of 95°C, duration of 45 min, in the presence of a nonionic surfactant, a H₂O₂ stabilizer, a sequestering-dispersing-colloid protector agent, 2.3 mL/L NaOH 38°Be and 5,8 mL/L H₂O₂ 30%), followed by dyeing with a bi-functional reactive dyestuff and drying (different temperature and duration);
- **sample codes X₁ and X₂**: a pre-treatment in single phase with genetically modified enzymes (Integenzy AE-DT-OK – Wuhan Universal Color & Biochemistry – China), followed by bleaching in the same bath, in 2 variants (X₁ - in a strong alkaline medium respectively 7g/L NaOH 38°Be and X₂ - in a mild alkaline medium respectively 4,14 g/L NaOH 38°Be), followed by dyeing with a bi-functional reactive dyestuff and drying (different temperature and duration);
- **sample code X₃'**: an enzymatic treatment with an alkaline pectinase (BioPrep 3000L – Novozymes - Denmark), followed by bleaching in subsequent phase (at temperature of 98°C, duration of 60 min, in the presence of a nonionic surfactant, a H₂O₂ stabilizer, a sequestering-

dispersing-colloid protector agent, 4 mL/L NaOH 38°Be and 15 mL/L H₂O₂ 30%), followed by dyeing with a bi-functional reactive dyestuff and drying (different temperature and duration);

- **sample code X₄**: a pre-treatment in single phase with a multiple action chemical auxiliary (Sirrix SB- Clariant - Switzerland), followed by dyeing with a bi-functional reactive dyestuff and drying (different temperature and duration).

2.3 Physical-chemical and physical-mechanical measurements

Physical-chemical and physical-mechanical characteristics of knitted fabrics containing PCMs have been assessed, as follows:

- **before dyeing**, in order to determine the preliminary treatment performance, from the point of view of the whiteness degree (SR EN ISO 105 J 01:2003) and hidrophilicity (drop test - SR 12751/1989 and absorbency test–SR 6146/1989);
- **after dyeing**, in order to determine the dyeability and color fastness, respectively: colour differences (SR EN ISO J01:2003), washing fastness (SR EN ISO 105-C 06:1999), acid perspiration fastness (SR EN ISO 105-E 04:2009), alkaline perspiration fastness (SR EN ISO 105-E 04:2009), rubbing fastness (SR EN ISO 105-X12:2003);
- **after preliminary treatment – dyeing – drying**: mass (SR EN 12127-2003), density (SR 5903-1993), thickness (SR EN ISO 5084/2001), maximum force - GRAB method (SR EN ISO 13934/2-2002), elongation at maximum force (SR EN ISO 13934/2-2002), abrasion resistance - NU MARTINDALE method (SR EN ISO 12947-2/2002), pilling effect - NU MARTINDALE method (SR EN ISO 12945-2/2002).

Thermal properties (heat of fusion and melting peak) were measured by means of DSC.

3. RESULTS AND DISCUSSION

Physical-chemical and physical-mechanical analyses were made at the beginning, before dyeing, in order to determine the preliminary treatment performance from the point of view of the whiteness degree and hidrophilicity and also to assess the pre-treatment influence on characteristics of knitted fabrics.

Whiteness degree of knitted fabrics 70% cotton/ 30% Smartcel Clima after preliminary treatments is shown in Figure 2.

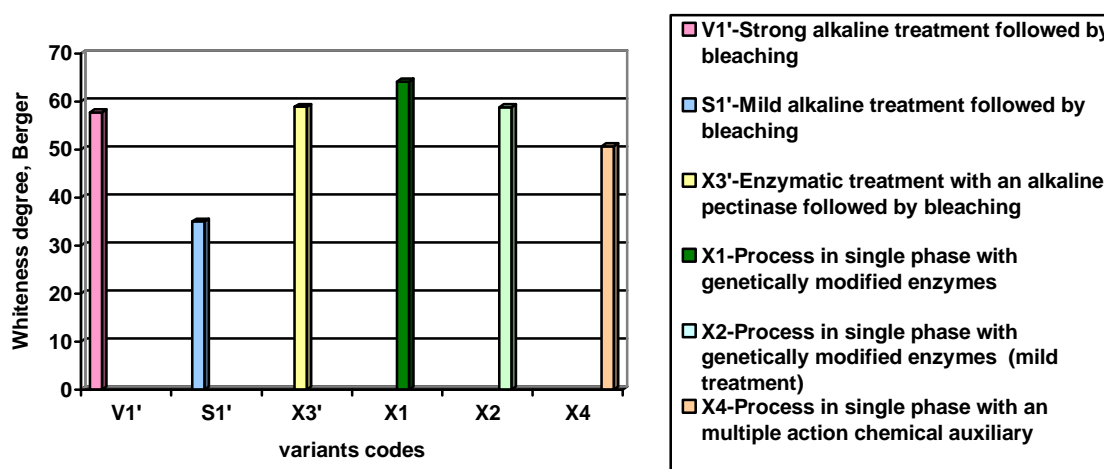


Figure 2: Whiteness degree of knit fabrics made of 70% cotton/ 30% Smartcel Clima after pre-treatments in subsequent or single phase.

Higher values of the whiteness degree were found in enzymatic pretreatment variants (X_1 , X_2 and X_3') when compared with the strong conventional alkaline treatment (V_1'). Lower values of the whiteness degree are obtained in the treatment made in single phase (X_4) and in the case of mild alkaline treatment S_1' .

Water absorbency of knitted fabrics made of 70% cotton/ 30% Smartcel Clima after preliminary treatments is shown in Figure 3.

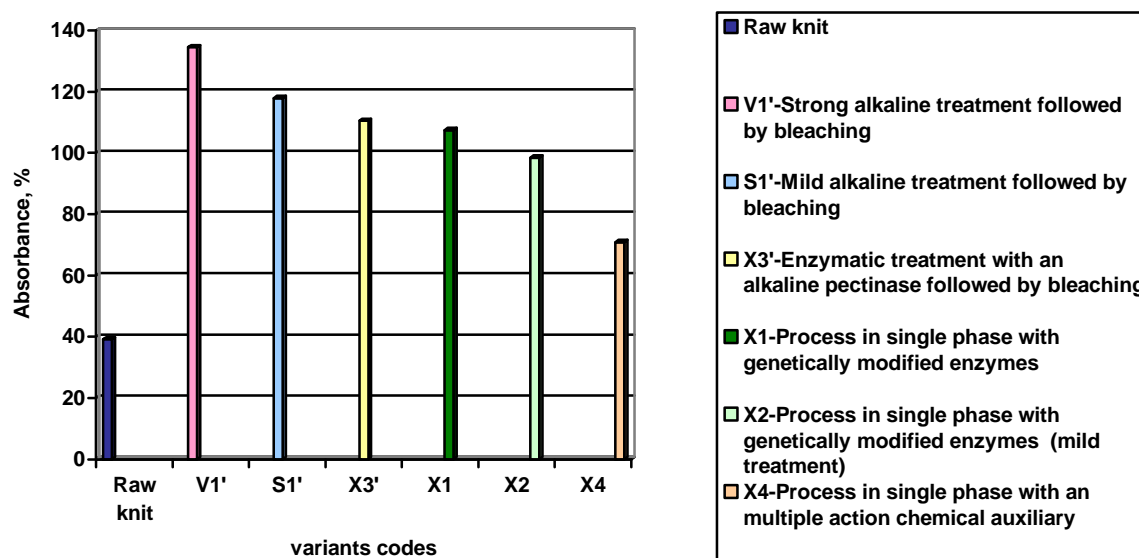


Figure 3: Water absorbency of knitted fabrics made of 70% cotton/ 30% Smartcel Clima after pre-treatments in subsequent or single phase.

In terms of hydrophilicity, determined by the drop test and water absorbency, the following can be noticed:

- pre-treatments in successive phases (V_1' , S_1' , X_3') provide a very good hydrophilicity (below 1 second – in accordance with the drop test), corresponding to the carrying out under good conditions of subsequent dyeing treatments; pre-treatments in single phase (X_1 , X_2 , X_4) provide a lower hydrophilicity expressed by drop test, with values between 1-3 seconds;
- in the case of the single phase pre-treatments good values of hydrophilicity for the treatment with genetically modified enzymes and higher concentrations of NaOH (variant X_1 with 7 mL/L NaOH 38 ° Be) are obtained; by decreasing the concentration of NaOH from 7 mL/L NaOH 38°Bé up to 4.14 mL/L NaOH 38°Bé (X_2 variant), the water absorbency decreases;
- from the analyzed treatments, the pre-treatment with Sirrix SB multifunctional auxiliary shows the lowest hydrophilicity.

Physical-mechanical characteristics of knits after the preliminary treatments are summarized in Table 1.

<i>Sample code</i> <i>Characteristic</i>	Untreated knit	V ₁ '	S ₁ '	X ₁	X ₂	X ₃ '	X ₄
Mass, g/m ²	172	225	236	234	235	225	229
Density/10 cm (wale no./horizontal)	102	117	126	117	119	108	121
(course no./vertical)	174	206	198	202	202	208	203
Thickness, mm	0.725	0.914	0.938	0.902	0.911	0.93	0.944
Maximum force, N horizontal	168.9	196.0	189.5	189.1	201	208	188.2
vertical	310	345	338	338	319	332	345
Elongation at maximum force, % horizontal	135.6	159.4	156.4	173.6	170.8	155.8	197.2
vertical	53	71.1	67.0	72.7	70.2	75.2	74.8
Abrasion resistance, no. of cycles (pressure 9Kpa)	19.828	38.500	35.000	39.242	42.362	44.659	37.814
Pilling effect, Marks (7000 cycles)	3	3	4	4	4	4	3

Table 1: Physical-mechanical characteristics of knitted fabrics made of 70% cotton/ 30% Smartcel Clima after preliminary treatments

In terms of physical and mechanical properties of pre-treated knitted fabrics (before dyeing) the following can be noticed:

- after pre-treatments it occurs the shrinkage of knitted fabrics, leading to increased values of the mass (g/m²), density/10 cm and thickness (mm) characteristics;
- at the same time the increase of maximum force on the horizontal and vertical direction takes place;
- in terms of abrasion resistance, the following variants are highlighted: X₂ variant (with genetically modified enzymes and low concentration of NaOH), X₃' variants (with alkaline pectinase followed by bleaching), for which the highest values of these characteristics were obtained (ranging between approx. 42.000-44.000 cycles);
- at the same time, the abrasion resistance of the pre-treated variants is doubled as compared to raw knit; this behavior is correlated with increased density on the horizontal and vertical direction;
- in terms of the tendency of pilling formation, we can estimate a slightly lower trend in pre-treated variants S₁' (mild alkaline-bleaching pre-treatment), X₁ and X₂ (pre-treatment in single phase with genetically modified enzymes) and X₃' (enzymatic pre-treatment with alkaline pectinase followed by bleaching).

The physical-mechanical characteristics of knits after reactive dyeing are summarized in Table 2.

<i>Characteristic</i> \ <i>Sample code</i>	V ₁ '	S ₁ '	X ₁	X ₂	X ₃	X ₄
Mass, g/m ²	219	235	226	225	225	233
Thickness, mm	0,91	0,92	0,89	0,89	0,92	0,91
Density/10 cm (wale no./ horizontal)	116	114	114	114	111	115
(course no./vertical)	212	209	209	209	213	209
Maximum force, N						
orizontal	181,1	193,7	191,1	193,9	190,03	192,2
vertical	316	317	310	355	338,6	344
Elongation at maximum force, %						
orizontal	177,0	200,0	200,0	191,0	197,6	264
vertical	82,4	84,5	89,1	87,3	91	88,1
Abrasion resistance, no. of cycles (pressure 9Kpa)	28.773	32.799	28.144	35.257	50.371	48.92 1
Pilling effect, Marks (7000 cycles)	2-3	3-4	2-3	2-3	3-4	2-3

Table 2: Physical-mechanical characteristics of knitted fabrics made of 70% cotton/ 30% Smartcel Clima after reactive dyeing

In terms of physical-mechanical properties of knitted fabrics after dyeing, the following can be mentioned:

- there are no significant differences between variants in terms of mass, thickness, density characteristics;
- mild alkaline-bleaching pre-treatment (variant S₁') induces higher levels of maximum force on the horizontal direction, by approx. 7%, as compared with the conventional variant of strong alkaline-bleaching pre-treatment (variant V₁');
- the highest abrasion resistance values of dyed knitted fabrics are obtained in X₃' variant (pretreated with alkaline pectinase followed by bleaching), followed by variant X₄ (pretreated in single phase with multiple action chemical auxiliary Sirrix SB), variant X₂ (with genetically modified enzymes and low concentration of NaOH) and variant S₁' (mild alkaline-bleaching pre-treatment);
- the tendency of pilling formation is lower in enzymatically pre-treated variant X₃' and mild-alkaline bleaching pre-treatment variant S₁', the obtained marks being 3-4, as to 2-3, obtained in the case of the other treatment variants.

In order to determine the dyeing process performance, color differences and color fastness have been performed. The results obtained are given in Table no. 3 and Table no. 4.

Sample code	X	Y	Z	Colour difference					Observation
				DL*	DC*	DH*	DE*	Mark	
V ₁ ' (Witness)	45.4 8	35.3 2	3.8 8	REFERENCE					
S ₁ '	45.3 6	35.3 9	3.5 3	0.05	1.70	1.44	2.23	4-5	saturated, yellower
X ₁	46.6 8	36.3 8	3.7 5	0.81	1.91	1.01	2.31	4-5	lighter, saturated, yellower
X ₂	46.7 8	36.6 3	3.9 2	1.00	1.09	1.20	1.90	4-5	lighter, saturated, yellower

X₃'	46.0 1	35.5 5	3.5 8	0.17	2.19	0.24	2.21	4-5	lighter, saturated, yellower
X₄	46.2 4	35.9 7	3.6 2	0.50	2.15	1.03	2.43	4-5	lighter, saturated, yellower

Table 3: Colour differences of knitted fabric made of 70% cotton/30% Smartcel Clima dyed with bi-functional reactive dyes

Sample code		V₁'	S₁'	X₁	X₂	X₃'	X₄
Fastness properties							
Washing fastness, 40°C	Change of shade	5	5	5	5	5	5
	Staining of CA	5	5	5	5	5	5
	CO	5	5	4-5	5	5	4-5
	PA	5	5	5	5	5	5
	PES	5	5	5	5	5	5
	PAC	5	5	5	5	5	5
	WO	5	5	5	5	5	5
Acid perspiration fastness, pH=5.5	Change of shade	4-5	5	5	4-5	4-5	4-5
	Staining of CA	5	5	5	5	5	5
	CO	4	4	4-5	4	4	4
	PA	4-5	5	5	5	5	5
	PES	5	5	5	5	5	5
	PAC	5	5	5	5	5	5
	WO	5	5	5	5	5	5
Alkaline perspiration fastness, pH=8	Change of shade	4-5	5	4-5	4-5	4-5	4-5
	Staining of CA	5	5	5	5	5	5
	CO	4	4	3-4	4	3-4	4
	PA	5	5	5	5	5	5
	PES	5	5	5	5	5	5
	PAC	5	5	5	5	5	5
	WO	5	5	5	5	5	5
Rubbing fastness	Dry	4-5	5	4-5	5	4-5	5
	Wet	4	4-5	4	4-5	4	4-5

Table 4: Fastness properties of knitted fabric made of 70% cotton/30% Smartcel Clima dyed with bi-functional reactive dyes

After the pre-treatment and dyeing process with bi-functional reactive dye (Kemazol Giallo BF-3RS), the following can be mentioned:

- as expected, there are color differences between the dyed samples, according to the preliminary treatment applied;
- as compared with the reference sample (V₁'), total color difference in absolute value (DE*) of samples pre-treated in different variants, ranges between 1.9 and 2.43; the positive values of DC* indicate that samples are more intense and higher in chroma (saturated) and the positive values of DL* indicate that samples are lighter;
- in terms of fastness, the following can be noted:

- regardless of the applied pre-treatment, washing fastness of the dyed knitted fabrics is high; the marks obtained for change of shade and staining of the multi-fiber standard range between 4-5/5;
- acid and alkaline perspiration fastness is good, with marks of 4-5/5 at change of shade and marks of 4/5 at staining of multifiber standard, except for samples pretreated in X₁ and X₃ variants', which have marks of 3-4 in staining of cotton sample in alkaline perspiration solution;
- dry rubbing resistances are very good for all treatment variants, with marks of 4-5/5; wet rubbing resistances are good, with marks ranging from 4/4-5.

The influence of overall pre-treatment-dyeing-drying process on the heat of fusion of knitted fabrics made of 70% cotton/ 30% Smartcel Clima is presented in Table 5.

Sample codes	ΔH , J/g	ΔH decreasing (%)	Max peak ,°C
Raw knit (untreated) - REFERENCE	4.64	-	29.17
V₁' Variant : Strong alkaline treatment followed by bleaching & dyeing & drying			
dried at 110 °C for 3'30"	3.52	24	28.16
dried at 120 °C for 2'30"	3.81	18	28.55
dried at 130 °C, 2'	4.09	12	28.48
S₁' Variant : Mild alkaline treatment followed by bleaching & dyeing & drying			
dried at 110 °C for 3' 30"	3.78	18	28.35
dried at 120 °C for 2'30"	4.03	13	29.16
dried at 130°C for 2'	4.14	11	28.92
X₃' Variant : Enzymatic treatment with an alkaline pectinase followed bleaching & dyeing & drying			
dried at 110 °C for 3' 30"	4.07	12	29.24
dried at 120 °C for 2'30"	3.56	23	29.45
dried at 130°C for 2'	3.83	17	28.91
X₂ Variant : Process in single phase with genetically modified enzymes (mild treatment) followed by dyeing & drying			
dried at 110 °C for 3' 30"	4.21	9	28.88
dried at 120 °C for 2'30"	4.25	8	28.92
dried at 130°C for 2'	4.66	-	27.30
X₄ Variant : Process in single phase with an multiple action chemical auxiliary followed by dyeing & drying			
dried at 110 °C for 3' 30"	3.74	19	30.07
dried at 120 °C for 2'30"	4.09	12	29.59
dried at 130°C for 2'	3.94	15	29.77

Table 5: Heat of fusion of knitted fabrics made of 70% cotton/ 30% Smartcel Clima after overall finishing process

On the whole, there are no significant differences between the applied finishing variants in terms of the influence on the latent heat, except for the process in single phase with genetically modified enzymes (X₂), where a lower decreasing of ΔH obtained. Variants tested lead to the decrease of the latent heat, ranging between approx. 10%÷24%, without any significant influence on the maximum peak.

Drying parameters seem to have an important influence over latent heat. The use of higher drying temperature (120-130°C) and short duration (2 min and 30 seconds - 2 min) lead to a smaller reduction of latent heat compared with the reference.

4. CONCLUSIONS

In the case of knits made of fiber blends made of 70% cotton/ 30% Smartcel Clima, with reference to finishing process, the following conclusions arise:

- pre-treatments can be done in successive phases or in a single phase, with good results in terms of hydrophilicity, whiteness degree, dyeability and dyeing evenness, without negative influence on physical-mechanical characteristics of knitted fabrics;
- low concentration of NaOH, in the case of alkaline pre-treatment, or using the enzymatic pre-treatment alternatives, induces higher values of maximum force, abrasion resistance and lower tendency of pilling formation;
- color fastness properties are very good and good, with marks obtained for change of shade and staining of the multi-fiber standard range between 4/4-5/5;
- the pre-treatment-dyeing-drying process as a whole, leads to changes in the latent heat, as compared with the raw knit, ranging between 10% ÷ 24%, without any significant influence on the melting temperature (maximum peak).

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ULTRASOUND ON SURFACES TREATMENT

European Project SONO – # 228730

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Abstract: *Ultrasound was proved to be an efficient tool in surfaces treatment for different purposes: cleaning, preparing a surface for further process, enhancing catalytic reactions, improving textiles dyeing, electroless plating and most recently in generating and coating fabrics with nano sized metal oxides.*

The presentation is an introduction to the world of ultrasonics starting with fundamentals of sonochemistry, examples of how ultrasound helps surface treatment and how it can be employed in the textile industry.

A presentation of ultrasonic equipment developed during the SONO project will be briefly discussed.

Some other areas in which ultrasound could be employed as a means to modify surfaces to increase performances of several processes such as: extraction of useful compounds from biomasses, chemical synthesis, emulsification etc., as well as several possible setups of ultrasonic devices, will be briefly presented.

FILTER TEXTILES FOR INDUSTRIAL APPLICATIONS

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Keywords: filtration, filter textiles, filter fabrics

Abstract: *Industrial activities involve complex processes of energy and matter transformation from their initial phase when they are generically known as raw materials to their final forms when they are finished products. Phase transformation processes often contain thermal, chemical and physical transfer phenomena, whose development involves temporary mixtures of substances. The completeness of processes is conditioned by removing provisional components, usually solid particles and keeping liquid or gas components for their utilization in the final destination or processing in new stages.*

The gaseous and liquid media require various filtration techniques as a separation method of solid particles. Most of these techniques involve the use of filter fabric as a barrier. Pore sizes, fabric thickness, reaction to the working environment are factors that ensure the quality and efficiency of the filtration process.

Filtration is a complex phenomenon consisting of the combination of surface filtration and depth filtration having the auto-filtration effect by the fabric layer which is formed on the surface of the filter fabric.

This paper presents the results obtained in computer-aided design by means of specialized software and the production of mono and multi-layer filter fabrics.

Raw materials (cotton, polyester, polypropylene yarns), mono and multilayer textile structures, with applications in industries such as metallurgy, food industry, building materials, chemical industry were studied.

The types of fluids subject to filtration consisted in water-based liquids or industrial oil and gases.

The fabrics obtained have weights ranging between 200 g/m² - 600 g/m², breaking load 150 N-500 N, width of 60-200 cm, permeability 50-500 l / m² / sec, the retained particles having sizes over 5 μm.

1. INTRODUCTION

European textile industry has a long tradition in the management of innovation and creativity and despite the fierce global competition and significant relocation of

manufacturing of the countries with cheap labor force, continues to represent one of the basic industries of the European economy. Moreover, the importance of textiles has been transposed by creating a platform specific to this domain and that is the European Technology Platform for Textiles and Clothing.

One of the three main domains of interest of this platform is to categorize the textiles as technical articles and to extend their applicability to many industrial sectors and new application areas.

Among technical articles, filter fabrics have proven useful, and the market for these products is continually growing. The need of having finer filtration and effluents (water and air) as clean as possible (pure), determined the filters suppliers to become specialized in a small number of application areas, since it is impossible to be an effective supplier for a large number of markets.

Woven technical textiles meant for filtration impose on the market of the products in this domain due to their advantages: reduced clogging, high temperature resistance, high chemical resistance, abrasion resistance, low deformation, etc.

Due to the structural-rheological characteristics, fabrics are often taken as a flat filter media. To meet the demands imposed by the operation within industrial installations and the community demands, filter fabrics shall meet several conditions, which are determined mostly by the structural characteristics and partly by the finishing processes. Few examples of these demands are the following:

- the existence of adequate structures to ensure high filtration capacity, high purification degree of elements and a minimum hydraulic resistance;
- high mechanical strength and stability to chemical, thermal, corrosive and biological agents;
- high degree of smoothness of the filter surface, which favours the easy and complete separation of the residue and filter reclaiming;
- structure homogeneity as a factor which influences the quality of filtration.

2. ASPECTS REGARDING THE FILTRATION PROCESS

Daily activities, the contemporary lifestyle specific to industrialized societies determine complex processes and activities meant to provide products, raw materials or working conditions specific to certain well defined domains.

Industrial-type activities frequently involve complex operations and processes whose development requires a mixture of certain substances for varying periods of time, followed by their partial or total separation, after the process finalization. The control activities of physical-chemical composition of a reaction phase or finished product maintain some components under certain limits, so that the final product characteristics range within the required limits. It is also known that chemical reactions often occur with the removal of certain reaction products or components from the reaction system.

On the other hand, the development of industrial processes or economic phenomena is possible only by maintaining the environmental composition parameters within certain limits (content of impurities, moisture and temperature).

For all these aspects filtration processes were necessary.

Defined as a process of separation by selective retention of particles that exceed a certain size, in order to eliminate it from the system, filtration is a phenomenon necessary in industrial processes. Carrying out this process is possible by acting at the surface or inside a filter membrane.

Filtration is essentially a physical phenomenon, based on the ability of solid particles (and gels) to penetrate or not a filtration barrier, using as an access way the available spaces between the constituent elements of this barrier. Most of the times the physical phenomenon is also accompanied by a chemical component, consisting of the molecular reactions between the product subject to filtration and the filtration barrier or between the fluids to be filtered and the particles that shall be retained.

The role of filtration barrier in retaining the solid particles occurs since the beginning, being the reference element in defining the filtration capacity. Once the fabric (filtration barrier) is crossed by the fluid subject to filtration, the auto-filtration starts through the free spaces between the particles that gather on the fabric surface. The auto-filtration process continues until the limit of efficiency, consisting of filtration auto-blocking having the following results: increasing the pressure in the filtration installation, reducing the flow of fluid (gas or liquid) collected from the installation, or even breaking the filtration barrier.

3. THE PRODUCTION OF FILTER FABRICS

Further on, the research results in the case of the filtration barrier which is provided by the woven fabrics are presented.

The production of woven filter textiles necessary for a certain environment is based on the following stages:

- physical-chemical evaluation of the working environment: temperature, chemical composition, pH, granulometry, type of filtration installation (filter disc, filter press, etc.);
- identification of raw materials adequate to be used in the environment to be filtered;
- woven structure design;
- identification of technologies and equipment afferent for the transformation of the designed structure into filter woven fabric;
- specific technological design;
- weaving of the filter textiles
- laboratory tests on the physical – mechanical characteristics;
- industrial experiments.

3.1 THE ANALYSIS OF THE NEEDS AND FILTRATION ENVIRONMENT IN THE INDUSTRY

As part of the research, potential economic agents who are users of filter fabrics, companies that use in their current activity woven filters in the technological stages of the production process or to prevent environmental pollution have been identified. Among them, there were companies in the food industry, chemical industry, metallurgy, machine building, etc.

The economic agents have in use filtration installations composed of: disc filters (alumina industry), high capacity filter presses (industry of polyols and polyethers), low capacity filter presses (food industry, oil filter industry).

Also, filtration environments with a variable pH between 2 ÷ 10, working temperature of 20 ÷ 160°C and working pressure of 2 ÷ 300 bar were identified. Chemical composition of effluents showed the following mixtures of products: water and oil, water and electrolytes, hot gas, hot gas mixtures. Granulometric analysis of the effluents subject to filtration showed particles of impurities with size ranging between 0.5 ÷ 30 µm.

Analyzing the conditions specific to the working environments, the raw materials adequate to be used were: polyester, polypropylene, cotton. These were used as spun or filament yarns.

In some cases, to ensure the specific conditions of filtration (filtration degree, mechanical strength during filtration) the selection of low-twist or textured yarns was necessary.

3.2 WOVEN STRUCTURE DESIGN

A software for designing filter fabrics for both simple structures and compound structures was created on the basis of the identified conditions and experience of specialists.

Software for designing filter fabrics with simple structures

The basic structural characteristics of the woven filters are the yarn fineness, yarn density and weave. Balanced and non-balanced woven structures are defined depending on the yarn density and fineness. In the balanced structure fabric, the warp and weft yarns have the same fineness and density, i.e. the same diameter d and the same density P . In the non-balanced structure fabric, the warp and weft yarns have different fineness, expressed by d_u and d^b diameters and different densities, expressed by P_u și P_b .

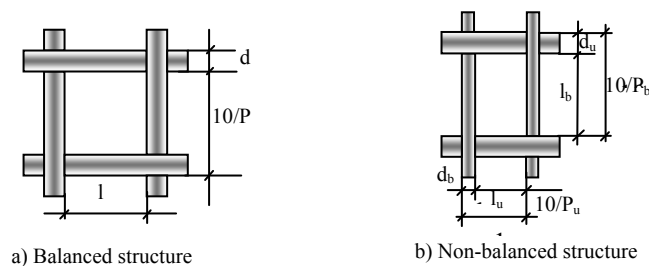


Fig. 1 The diagram of a woven fabric pore

Qualitative assessment elements of woven filter media with simple, balanced and unbalanced structure are:

- pore side (l , l_u , l_b), which is the distance between two consecutive yarns of the fabric measured horizontally or vertically;
- pore area (A_p) defined as the horizontal projection area of the fabric pore.
- active filtration area (S_a) which represents the degree of emptiness or the fabric porosity and is calculated as the ratio between the pore area and the total area of the fabric element:

$$S_a = \frac{l_p^2}{l^2} \cdot 100 \quad (\%) \quad (1)$$

- filter fineness (F) expressed by the number of stitches per unit length or the number of stitches per unit area (stitches/cm, stitches/inch, stitches/cm²)

The process is based on building a series of five algorithms for designing filter fabrics with simple structures that are used to identify structural and functional characteristics of the

existing filters, to redesign or design the filters according to the requirements of industrial processes.

Algorithm I, having as initial data the yarn diameter and density, allows the verification of the existing filter fabrics and the estimation of specific characteristics: pore size, filter fineness and active filtration surface.

Algorithm II used for the design and redesign has as initial data the yarn diameter and filter fineness and allows the determination of yarn density, pore size and active filtration surface.

Algorithm III, recommended in the design of filters, has as initial elements the pore diameter and pore size and allows the calculation of filter fineness and pore sizes.

Algorithm IV is suitable for designing filters, uses as initial elements the yarn diameter and active filtration area and allows the calculation of filter fineness and pore size.

Algorithm, recommended for design, uses as initial data the pore size and active filtration area and allows the calculation estimation of yarn density, yarn fineness and filter fineness.

Images of the design software for filter fabrics with simple structures and the editing modality of functional parameters:

Denumire	Simbol	Valoare	Unitate de masura
Diametrul firelor	d	0.15	mm.
Desimea firelor	P	17	fire/cm.
Finetea filtrului	F	17	ochiuri/cm.
Finetea mesh	F _m	43.18	ochiuri/inch.
Latura porului	l	0.438	mm.
Aria porului	A _p	0.1921	mm. ²
Suprafata activa	S _a	55.50	%
Constanta pentru calculul diametrului	A	0.0392	-
Finetea firelor	T	14.64	tex
Contractia firelor	a	5	-
Masa tesaturii	M	52.40	g/m ²

Denumire	Simbol	Valoare	Unitate de masura
Diametrul firelor de urzeala	d _u	0.20	mm.
Diametrul firelor de batatura	d _b	0.25	mm.
Desimea firelor de urzeala	P _u	10	fire/cm.
Desimea firelor de batatura	P _b	12	fire/cm.
Finetea filtrului	F _d	120	ochiuri/cm ²
Latura porului - transversal	l _v	0.8	mm.
Latura porului - longitudinal	l _h	0.583	mm.
Aria porului	A _p	0.4667	mm. ²
Suprafata activa de filtrare	S _a	56	%
Constanta pentru calculul diametrului	A	0.0334	-
Finetea firelor de urzeala	T _{tesu}	35.86	tex
Finetea firelor de batatura	T _{tesb}	56.03	tex
Contractia firelor	a _u	5	-
Contractia firelor	a _b	6	-
Masa tesaturii	M	109.28	g/m ²

Fig. 2 Example of designing filter fabric with simple structure

Design software for filter fabrics with compound structures

This software is intended to be used as filter media for the fabrics with double or double weft compound structures. Since the filtration through compound structures is governed by the in-depth filtration principles, for them the priority functionality parameter is the porosity. Since the composite fabrics are bulky structures, formed in layers, their characterization is done by means of compactness degree. This is considered as a synthetic, global indicator for evaluating the structure of a woven product. The compactness degree of the fabric shows the extent to which the capacity of filling the fabric with yarns is used in terms of certain internal architecture and the emptiness degree of the fabric is its porosity.

For the analysis and design filter media with double weft compound structures three algorithms were developed:

Algorithm I. The design of double weft filters which are partially compactness unbalanced depending on the density of yarn systems and diameters. In this case the basic structural characteristics of the filter fabric: yarn fineness and density are known. The algorithm can be used to identify the specific characteristics of filters: the maximum pore opening and porosity. Thus, using this algorithm it can be determined whether the filter is in line with the features of a required filtration process. Based on the conclusions made after verification, **the redesign** of the fabric so that it complies with the requirements of use can be performed.

Algorithm II. The design of double weft filters which are compactness balanced depending on the yarn diameters and porosity. Initial data consist in the fineness of component yarns and porosity and by design calculations, yarn densities and maximum pore opening result from these. The algorithm can be also used to redesign the filter media as required during use, as the filter fineness is a feature that does not directly determine the fineness of filtration, but the process efficiency. Thus, the algorithm allows checking if the filtration pore size is necessary in the yarn fineness and diameter of a given fabric.

Algorithm III. The design of double weft filters which are compactness balanced depending on the density of yarn systems and diameters. This algorithm is used only for design according to the process requirements. Pore size implies that the composition of the filtrate is known, the filter being a calibrated restriction that retains the particles of a certain size. Porosity is a characteristic that determines the efficiency of filtration, the flow rate being determined by this parameter.

3.3 THE PRODUCTION OF FILTER FABRICS

Based on elements identified in the analysis made at the industrial economic agents, 26 variants of filter fabrics for retaining solid particles from media such as food oils, industrial oil and water emulsions, electrolyte solutions, hot gases, have been designed and developed using the described design software.

From the technological point of view, the results obtained in structural design stage were materialized by adopting two distinct technologies, namely by using the conventional shuttle machines and unconventional rapier weaving machines. These two technologies have features that lead to the achievement of specific features of filter materials such as: compactness, permeability, pore size.

For certain variants specific finishing operations were included in the technological flow (boiling, heat-setting, water repellent) with direct effects on dimensional stability, abrasion resistance and filtration capacity.

Using the results obtained in the design stage of woven structures, in the technologic design stage, different variants of woven fabric were obtained, which were physically-mechanically characterized and selected, as shown in Table 1 and Table 2. This was possible by using the conventional shuttle weaving machines and unconventional rapier weaving machines.

Table no. 1 Physical-mechanical characteristics of woven fabrics produced on conventional machines

No.	Characteristic	DANA Article		ELISABETA Article	ANA Article	ELA Article		
1	Destination	Hot gas filtration		Diluted electrolyte filtration	Concentrated electrolyte filtration	Polyether filtration		
		raw	finished	raw	raw	raw	finished	
2	Raw material	Filament polyester, 220 dtex x2		Spun polyester, Nm40/4	Filament, PP U 1100 dtex B2200 dtex	Filament, PP U 1100 dtex B 2200 dtex		
3	Width (cm)	142,5	143	102	102	150	135	
4	Mass (g/mp)	208	216	430	463	425	528	
5	Density U (fire/10cm)	280	290	274	280	250	262	
6	Density B (fire/10cm)	133	130	130	60	60	68	
7	Breaking force (N)	U	2259	2326	3246	8564	5688	5294
		B	969	960	2618	3856	4028	4354
8	Elongation (%)	U	32,8	31,4	31,4	3	3	64
		B	29,9	27,3	27,6			34,8
9	Air permeability (l/mp/sec) 20 Pa	120,8	73,7	276	8	58	32	
10	Finishing	Heat-set at 210°C		No finishing	No finishing	Heat-set at 155°C		

After analyzing the values obtained, shown in Table 1, the following aspects result:

- on the conventional weaving machine 4 new filter fabrics were for industrial filtration purposes were produced, using as raw material polyester and polypropylene yarns;
- the fabrics show mass values ranging between 220-530g/m² meant for polluting areas, having aggressive pollutants: gas with temperature above 150 ° C, aggressive electrolytes (alternating acidic and basic environment);
 - permeability of fabrics is 32 l/mp/sec-300 l/mp/sec at a pressure of 200 Pa.
 - to ensure the physical - mechanical characteristics, for certain variants thermal finishing treatments at a temperature of 155°C for PP fabric and 210°C for polyester fabric were used;
 - by heat-setting the dimensional stabilization was reached and the compactness of the fabrics showed in Ela fabric showed an increase in the mass from 425 g/m² to 528g/m².
 - the products were tested by the economic agents whose work requires the provision of anti-pollution measures, such as filtration.

Table no. 2 Physical-mechanical characteristics of raw fabrics produced on Optimax machine

No.	Characteristics	Sample P1	Sample P2	Sample P3	Sample P4	Sample P5	Sample P6	Sample P7	Sample P8	Sample P9
1	Width [cm]	204,5	199,5	197	196,5	197,5	196,7	199,8	200,5	196
2	Total mass [g / m ²] [g/ml]	327	605	476	498	483	518	684	673	810
		669	1207	938	978,6	934	1019	1367	1349	1588
3	Density [fire/ 10 cm] U B	320	342	340	335	338	344	336	334	323
		100	238	284	260	278	242	220	220	262
4	Breaking force [N] U B	1855	1698	1352	1638	1216	1681	1481	1716	1554
		503	1840	1705	1767	1810	2149	2990	3266	3927
5	Breaking elongation [%] U B	16,45	21,5	14,11	15,58	13,98	20,4	23,7	24,8	20,5
		5,88	9,76	11,32	11,69	11,77	12,29	12,59	13,59	14,21
6	Air permeability [l/mp/sec], 200 Pa	70	174,1	96,02	93,21	110,6	172	174	188	110
7	Thickness [mm]	0,756	1,39	1,086	1,086	1,086	1,82	1,244	1,56	2,34
8	Weft yarn fineness [Nm]	40/3	20/3	40/3	40/3	40/3	40/4	20/4	20/3	20/4
9	Weave	Plain	Double plain	Double D2/2	Double D2/2	Double D2/2	Double D2/2	Double D2/2	Double D3/1	Double D3/1
10	Apparent diameter [μm] U B	396	396	396	396	396	396	396	396	396
		396	516	396	396	396	396	404	584	516

The analysis of the values listed in 2 shows the following:

- *fabric width* had values ranging between 196 -200, 5 cm for the same width in the reed, 205 cm, respectively. Different width is determined by the different contraction of the weft yarn, which was generated by the different weaves used. The crimp of warp and weft yarns gives different contractions of yarns from the two systems, depending on the adopted density and yarn tension. The variants of fabric produced had in view obtaining a high degree

of weft yarn beat-up in order to reach a compact structure.

In turn, the compact structure provides high finesse of pores and their uniform distribution on the fabric surface.

- *fabric mass* has values ranging between 327 g/m² and 810 g/m².

The variable elements that led to obtaining mass values within the limits mentioned were the weave and weft yarn fineness. It is worth mentioning that all variants have been made of the same number of warp yarns draught with the same number of number of healds and the same draught in the reed. Variants P1, P3, P4, P5, are made with the same fineness of weft yarn, namely Nm 40/3. Of these, variant P1 shows the lowest mass value, as compared with the group P3, P4, P5. The difference consists in the weave used (double warp) which in the case of variants P3, P4, P5 allowed obtaining higher densities in the weft, implicitly a greater degree of yarn crimping from the two systems. As compared to 100 yarns/10cm, in the weft density of variants P1, P3, P4, P5, a weft density between 260 and 284 yarns /10 cm is obtained.

- *the weave* provided a uniform field of contraction of the three variants (being small variations in width and thickness between them), correlated with differences in mass and density. Unlike variant P1, in which the fabric width is the same with the width in reed width, in the 3 variants the weaving contraction reached 3%.

- *the breaking strength on the warp direction*, in the 3 variants (P3, P4, P5) is lower than the value obtained on the same direction, as regards sample P1 (which involves the same number of yarns/cm). This phenomenon can be explained by the different rate of participation in taking over the stress of double fabrics. Some of the yarns provide the binding of layers and therefore the number of yarns that takes the tensile stress is reduced.

- *the breaking strength on the weft direction*, in the 3 variants (P3, P4, P5) is higher than the value obtained on the same direction as regards sample P1 (correlated with increasing the weft density - yarns /cm). In variant P6, made with the same weave as variants P3, P4, P5, by using a thicker yarn (Nm 40/4) at a density comparable to that recorded in the group of variants P3, P4, P5 there is a proportional increase in mass, as well as a proportional increase in the thickness and breaking load.

Comparing variant P2 with variant P8, it can be noticed that at the same warp and weft yarn fineness, by using different double weaves there is a different mass (605 g/m² in P2 and 673 g/m² in P8) and a different thickness 1.39 mm in P2 and 1.56 mm in P8), a phenomenon explained by the number and amplitude of binding levels. The same correlation is found in the case of variants P7 having the mass of 684 g / m², thickness 1.244 mm and variant P8 with the mass of 810 g/m² and thickness of 2.34 mm.

4. CONCLUSIONS

The following relevant ideas on the correlation between the filtration medium, raw material used, type of filter fabric or the application field can be concluded:

⇒ For the filtration medium *wastewater*, such as water resulted from industrial or domestic activities filled with suspended solids, with variable and uncontrollable pH, fabrics made of 100% polyester yarns of spun and filament fibres are recommended. The type of filter used is the filter press with working pressure of up to 10 bar and the liquid medium subjected to filtration comprised solutions of electrolytes and polyethers. The fabrics can be successfully used in municipal wastewater treatment plants and in centers for the treatment of wastewater coming from economic agents. By its manufacturing in certain physical-mechanical parameters, this type of fabrics is successfully recommended to extractive industries, in the plants for iron ore flotation and for coal conditioning-preparation.

⇒ For the filtration medium *oil with impurities*, such as vegetable oils, phase filtration with the passage through "filter presses" equipped with fabrics of various finenesses, so to finally obtain a filtration fineness of 5 µm is necessary.

Filters for this domain were made of 100% cotton, spun yarns to ensure a high degree of filling the fabric and high mechanical resistance. These fabrics are used in the manufacture of filter elements for filter presses subject to frequent cleanings with water and steam jets. The filtered product in food or pharmaceutical industry imposes as a basic requirement for the filter material, the possibility of being cleaned (disinfected) by boiling at frequent intervals. This requirement is provided by cotton fibre which shows good hygienic-functional characteristics. In the industrial beneficiaries, after tests carried out on the filtration installation with 5-6 plates and an installation with 20 plates, respectively, under a work pressure of 7 bar, a very good behaviour resulted. In these beneficiaries, fabrics are subject to regular cleaning process by washing with detergent solutions, the results confirmed after 3 months of operation being very good.

⇒ For the filtration medium, *the gases with suspensions*, technologies in the metallurgical industry, where the passage of metal through various states of aggregation from ore to finished product is made with the involvement of abrasive mineral particles with quartz, silicon, manganese content, at temperatures of up to 220°C, filled with solid impurities, with a diameter of 10-30 µm, the recommendation would be the fabric made of 100% PES raw material, filament yarns.

The filter destination requires frequent shaking to eliminate the adherent impurities. To achieve an effective cleaning, a glossy contact surface provided by the polyester filament yarns is needed. In the industrial beneficiaries the fabric was tested for two media, one consisting of dolomite, limestone and silica powder, and another one containing carborundum powder, metal particles and carbon black. In both cases, the fabric is fixed in the installation as filter bags with circular section. For this domain, the fabric has been finished by heat-setting and by applying a special treatment of dry lubrication.

By using high performance current generation of raw materials, in accordance with specific requirements of economic agents whose technologic processes require filter fabrics, high performance filter materials in this field can be obtained.

Using filter materials in industrial processes leads besides the immediate economic effects to obtaining important results in environmental protection, eco systems and maintaining a high standard of life quality.

By promoting the new generation of filter materials the purpose is to reduce the existing disparities between Romania and European countries and to improve the perception on clean technology approach.

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DYNAMIC GARMENT SIMULATION USED FOR COMPUTER ANIMATION

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Abstract: *This paper presents the dynamic simulation steps for creating computer animation. The computer animation is the process used for generating animated images by using computer graphics. These animations are an important step in dynamic cloth simulation around the virtual human body. For this goal it is necessary to have the mannequins that can be created in specialized graphic software or to get these from 3D scanner. In this work two animations are proposed: one starts from virtual body from Vitus 3D scanner and another one from a 3D CGI rendering and animation software program. Another important point is the knowledge in dynamic cloth simulation that involves the internal and external forces that act on the textile surface.*

1. INTRODUCTION

At present there are two approaches:

- The first is the cloth object movement → textile surface dynamics represented by particle based model¹ in virtual environment (the cloth triangle movement that generates the interaction between neighbouring particles that are joined by springs of constant length).

The Choi and Ko particle based model consists in particle P (i,j) and interactions defined by spring length like S_i for structural relation and I_i for bending (figure 1).

The stretch is generated by the interaction forces between neighbouring particles (figure 1).

The stretching energy (E) between two particles¹ is given by the following mathematical relations (1):

$$E = \frac{1}{2} k_s \left(|x_{ij}| - L_s \right)^2, \text{ for } |x_{ij}| \geq L_s \quad (1)$$

$$E = 0, \text{ for } |x_{ij}| \leq L_s$$

$$E = \frac{1}{2} k_s \left(|x_{ij}| - L_s \right)^2, \text{ for } |x_{ij}| \geq L_s$$

$$E = 0, \text{ for } |x_{ij}| \leq L_s$$

Where:

$$x_{ij} = x_j - x_i;$$

$$x_i = \begin{bmatrix} x_i \\ y_i \end{bmatrix};$$

$$x_j = \begin{bmatrix} x_j \\ y_j \end{bmatrix};$$

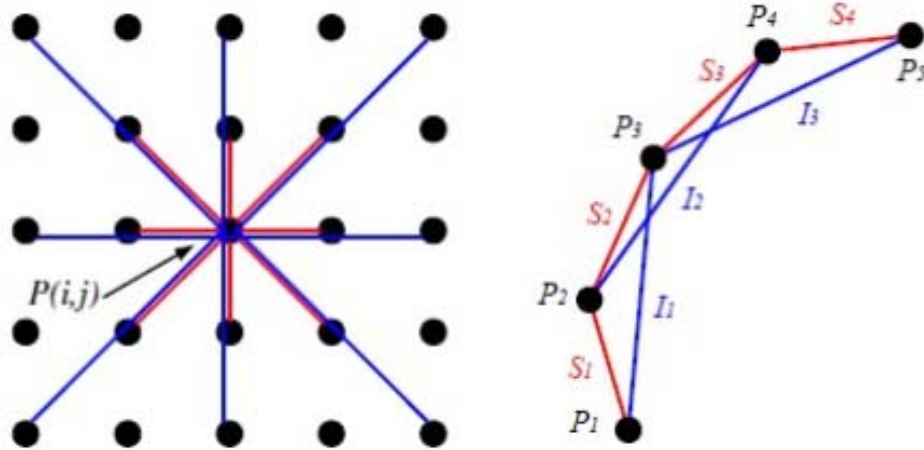


Figure 1: Particle based model interaction and connectivity

L_s is the distance between two neighboring particles and k_s is the stretching spring stiffness. The force (f_i) that acts in the particle i during the stretching process¹ is given by the following mathematical relations (2):

$$f_i = -\frac{\partial E}{\partial x_i} = k_s \left(|x_{ij}| - L_s \right) \frac{x_{ij}}{|x_{ij}|}, \text{ for } |x_{ij}| \geq L \quad (2)$$

$$f_i = 0, \text{ for } |x_{ij}| \leq L$$

The bend and the compression are generated between every particle (figure 1). The bending interaction energy is given by a circular arc shape approximation¹:

$$E = \frac{1}{2} k_b L_b k^2 \quad (3)$$

where L_b is the bending arc length, k_b is the bending spring stiffness.

The curvature k is given by:

$$k = \frac{2}{L_b} \sin c^{-1} \left(\frac{|x_{ij}|}{L_b} \right) \quad (4)$$

Where $\sin c(x) = \frac{\sin(x)}{x}$

It can be concluded that a force composed (5) of internal forces (f_{internal}) – stretching and bending forces, external forces (f_{external}) and damping forces (f_{damping}) acts on a particle.

$$F = f_{\text{internal}} + f_{\text{external}} + f_{\text{damping}} \Leftrightarrow \quad (5)$$

$$F = f_{\text{stretch}} + f_{\text{bend}} + f_{\text{external}} + f_{\text{damping}}$$

$$f_{damping} = cv, \text{ where } \underline{v} = \begin{bmatrix} v_{x1} \\ v_{y1} \\ v_{x2} \\ v_{y2} \\ \dots \end{bmatrix} \text{ a vector of particle velocities and } c \text{ is the damping coefficient}^1.$$

The dynamic simulation of the garment on the virtual mannequin involves the motion, velocity v and acceleration a .

The motion equations are:

$$\begin{aligned} v &= \frac{dx}{dt}; \\ a &= \frac{dv}{dt} = \underline{M}^{-1}F \end{aligned} \quad (6)$$

The $\underline{M} = \begin{bmatrix} m_1 & 0 \\ 0 & m_2 \end{bmatrix}$ is the diagonal mass matrix,

where m_1, m_2 are masses of two body particles in one dimension.

In computational mechanics, a mass matrix \underline{M} is a generalization of the concept of mass to generalized coordinates. The position of such a system has two degrees of freedom, the position of each particle, which can be described by the generalized position vector \underline{x}^1 .

The garment product dynamic simulation involves the body motion and is affected by³:

- the type of the fabric;
- the pattern design, pattern cuts on warp or weft direction;
- friction between body-garment, and garment parts (pleats or garments folds).
 - The second problem is the collision object movement → virtual mannequin.

The realistic motion depends on the degree of freedom of movement for each body part. For animation it is necessary to position the skeleton on the parametrical mannequin, to set and record different postures frame by frame².

2. MANNEQUIN DESIGN

If the body is captured from a 3D scanner it required a redesign process (figure 3) for obtaining a valid 3D area. The steps that are followed include the export file from ScanWorX software (figure 2.a) and the import in Rapidform for future transformation (figure 2.b). In Rapidform the redesign process consists in obtaining a continuous body surface from incomplete body surface. The body meshes are aligned and repaired in process based on surface point adding and retriangulation process.

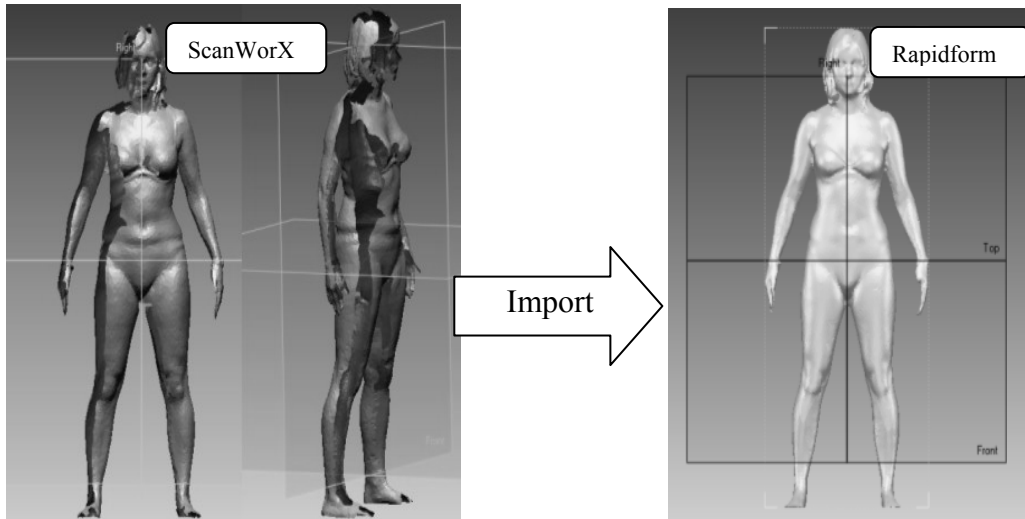


Figure 2: a) Scanned body –ScanWorX

b) Optimized body -Rapidform

For creating human body in specialized graphic software from standard primitives a hard work for sculpting the body is required. The advantage in this case is that it is possible to obtain a perfect symmetry of the human body. This body presents a mesh segmentation² (figure 3).

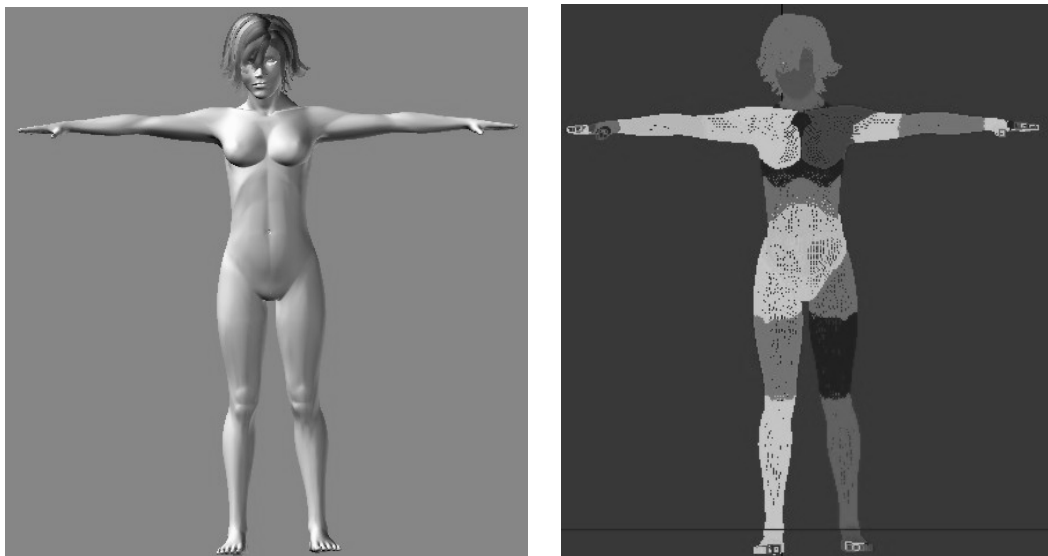


Figure 3. Virtual body –mesh segmentation

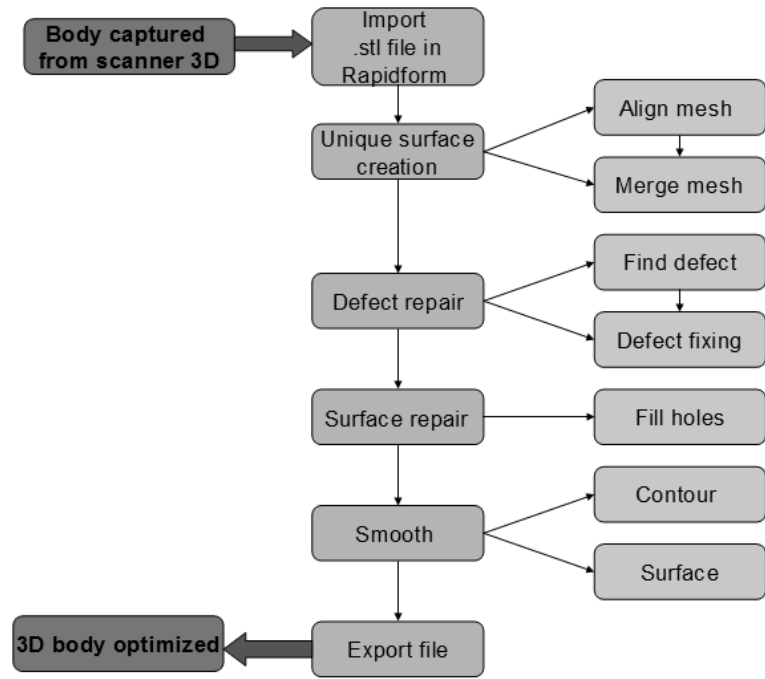


Figure 3: Rapidform redesign process

3. ANIMATION PROCESS

For dynamic simulation it is useful to use a hierarchical segmentation for redesigning the human body deformation in motion. In dynamic simulation the collision objects that can be formed of the virtual human body and the textile surface is required. For predicting the dynamic behavior it is important to know the textile surface forces that act on the cloth surface, the nature of collisions that take place, the rendering, the laws of dynamics (forces, acceleration and velocity) and the constraint points. In dynamic simulation the body and the fabric are in movement.

The realistic motion depends on the degree of movement freedom for each body part³. For animation it is necessary to position the skeleton⁴ on the parametric mannequin (figure 4), to set and record different postures frame by frame². For 3D animations, all frames must be rendered after modeling is complete.

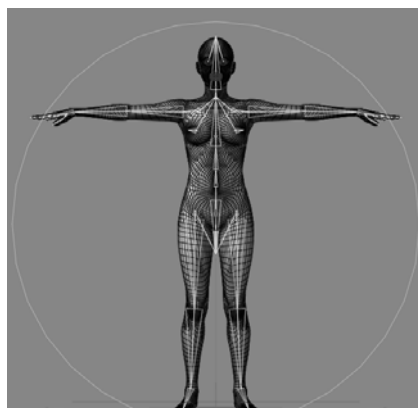


Figure 4: Skeleton position on the parametric mannequin

The body motion capture is done by using different postures (figure 5) after recording them frame by frame.



Figure 5: Different postures

The next step consists in 3D modeling of the garment (figure 6). The animation is made by using frames recording. On different frame we use different body posture and thus collisions between body and garment may appear. This problem can be resolved by changing the garment position – translation, rotation - around the virtual body. This repositioning must be followed by re-simulation.

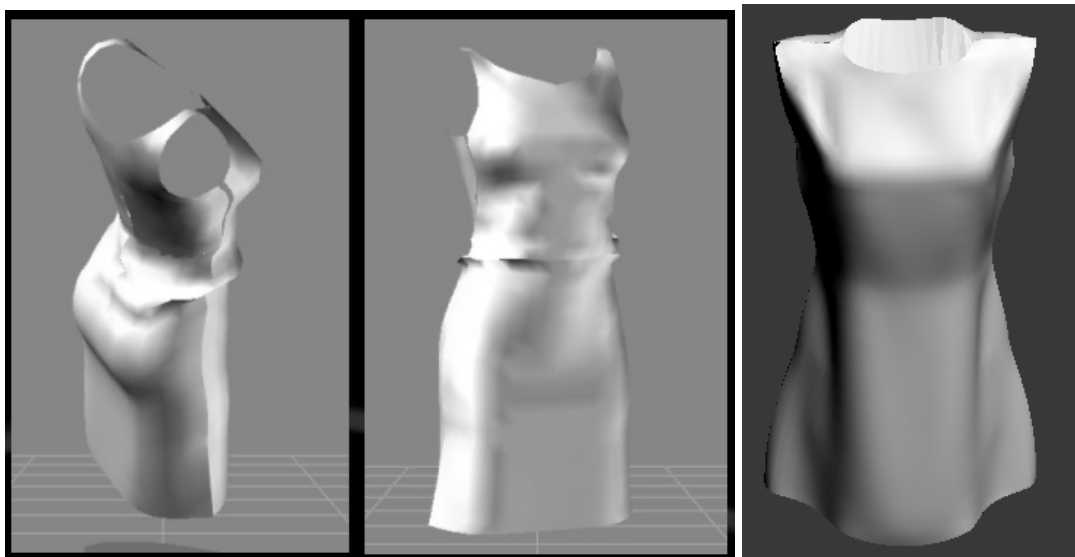


Figure 6: 3D garment model



Figure 7: Static simulation

As compared to the static simulation (figure 7), the mesh triangles intersection occurs in dynamic simulation (figure 8).

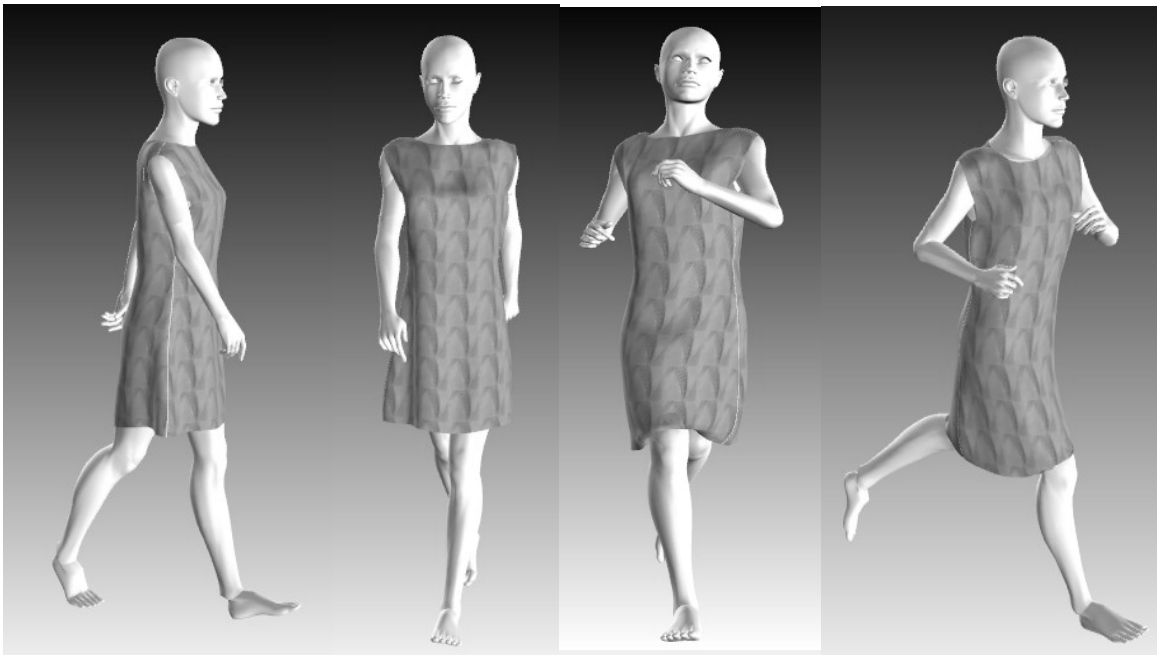


Figure 8: Dynamic garment simulation

4. CONCLUSIONS

The results of this simulation can be used for creating the virtual prototypes animation. The dynamic simulation is required in creating the realistic animation which is useful for virtual reality, games and for garment industry. The virtual animation can not replace the wearing tests from reality. The movement simulation advantage is that it is possible to see the constraints that may arise from cloth in the areas of seams or that are influenced by body postures.

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A DECADE OF RESEARCH ON THE UV PROTECTIVE FINISHING OF TEXTILES

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ABSTRACT: *Ultraviolet Radiation (UVR) harms the human health and the incidence of skin cancer is widely spreading all over the world. Therefore, nowadays there is a high demand for the textiles with UV protection property and the UV protective finishing of the materials is almost a common application. The demand is not only for “garments” or “shirts”, but also for the awnings, the tents and the curtains for the protection against the UV radiation coming from the sun. In the last decade, the UV protection has been the most popular topic of research in the literature and almost all aspects of the application have been dealt with in detail.*

This paper gives a critical review of works carried out at Marmara University in the field of UV protective finishing of textiles.

1. INTRODUCTION

Many researchers have recently been carried out intense research on the UV protection of textiles since the ultraviolet radiation (UVR) coming from the sun harms the human health and the incidence of skin cancer is widely spreading all over the world. The textile materials have different UV protection properties, depending on their fibre types, structure, whether they are wet, dry or treated by a suitable UV absorber. The UV protection can be expressed by the UPF value, which can be calculated in accordance with the AS/NZS 4399:1996 standard, using the transmittance values of the fabrics from 290 nm to 400 nm wavelength range. The transmission values of the dyed and treated fabrics in the 290-770 nm wavelength range can be used to calculate the “shade factors” and the % UVR blocking in accordance with the AS 4174-1994 standard.

A detailed literature survey on the treatment of textile fibres with the UV absorbers is given in the Reference section⁸⁻⁴⁷. Dyed materials have better UPF values than the undyed materials. The UV absorbers can be applied either in the dyebath or after the dyeing process, and both the exhaustion and the padding processes can be employed in the application of the UV absorbers.

2. EXPERIMENTAL PART

2.1 Aim of the Experimental Works

The aim of the experimental works¹⁻⁷ was to apply various commercially available UV absorbers to different types of knitted or woven fabrics, either solely or in the dyeing stages

by exhaustion, in order to investigate the UV protective properties of the materials as well as the effects of the UV absorbers on the colour yields.

2.2 Fabrics

The following knitted or woven fabrics were used throughout the experimental works:

- 100% cotton knitted fabric, jersey, 155 g/m², 0.68 mm. thick
- 100% viscose woven fabric, plain weave, 131 g/m² with a 0.3 mm. thick
- 100% PES knitted fabric, interlock, 190 g/m², 0.84 mm. thick
- 100% PES knitted fabric, jersey, 266 g/m², 0.98 mm thick
- 100% PES woven fabric, voile, 54 g/m², 0.15 mm thick
- 100% PES woven fabric, satin, 132 g/m², 0.27 mm thick
- 97.5/2.5% viscose/Lycra knitted fabric, jersey, 208 g/m², 0.83 mm. thick
- 50/50% polyester/cotton knitted fabric, jersey, 147 g/m², 0.73 mm. thick
- 55/45% polyester/viscose knitted fabric, jersey, 209 g/m², 0.74 mm. thick

All of these fabrics were pretreated and ready for dyeing, and were free of optical brightening agents.

2.3 Instruments Used for the Treatments and Testing

Perkin Elmer Lambda 9 UV-Visible Spectrophotometer with a spherical attachment and also SDL Atlas M284D were used for transmission measurements. Roaches HT Laboratory Type Dyeing Machine was used for the applications of the UV absorbers.

2.4 UV Absorbers

The following commercially available UV absorbers were used throughout.

- Tinofast CEL (Ciba)
- Rayosan C Paste (Clariant)
- Cibafast P (Ciba)
- Fadex ECS Liquid (Clariant)
- UV-SUN CEL Liq. (Huntsman)
- UV-SUN PES (Huntsman)

Tinofast CEL (Ciba), Rayosan C Paste (Clariant) and UV-SUN CEL Liq. (Huntsman) were used for cellulosic fabrics and the cellulosic blended fabrics, and Cibafast P (Ciba), Fadex ECS Liquid (Clariant) and UV-SUN PES (Huntsman) were used for 100% polyester or polyester blended fabrics. The results of the applications of UV-SUN CEL and UV-SUN PES were given elsewhere¹⁻³.

2.5 UPF Measurements

The UPF (Ultraviolet Protection Factor) calculations were carried out in accordance with the methods described in AS/NZS 4399:1996 standard.

UPF- Ultraviolet Protection Factor.

$$UPF = \frac{E_{\text{eff}}}{E'} = \frac{\sum_{290}^{400} E_{\lambda} \cdot S_{\lambda} \cdot \Delta\lambda}{\sum_{290}^{400} E_{\lambda} \cdot S_{\lambda} \cdot T_{\lambda} \Delta\lambda}$$

E_{λ} : relative erythema spectral effectiveness,

S_{λ} : solar spectral irradiance, $W \cdot m^{-2} \cdot nm^{-1}$

T_{λ} : spectral transmittance of the item,

$\Delta\lambda$: wavelength step in nm

λ : wavelength, nm

For the purposes of labelling, sun protective clothing can be categorized according to its rated UPF as given in Table 1.

Table 1: UPF Classification System in AS/NZS 4399:1996.

UPF Range	UVR Protection Category	Effective UVR transmission (%)	UPF Ratings
15 – 24	Good protection	6.7 – 4.2	15 , 20
25 – 39	Very Good protection	4.1 – 2.6	25, 30, 35
40 – 50, 50+	Excellent protection	≤ 2.5	40, 45, 50, 50+

2.6 Dyes

The UV absorbers were used in the dyeing stages by exhaustion in some applications. Accordingly, Dianix Yellow S-4G [DyStar], Dianix Red 2BSL- FS 150 [DyStar] (C.I. Disperse Red 184) and Dianix Blue GSL 400 [DyStar] (C.I. Disperse Blue 165) were used for the dyeing of 100% PES fabrics, and Remazol Yellow GR [DyStar] (C.I. Reactive Yellow 15) was used for the dyeing of 100% cotton and 100% viscose fabrics.

2.7 Application of Tinofast CEL

Tinofast CEL was applied to undyed 100% cotton, 97.5/2.5% viscose/Lycra, 50/50% polyester/cotton and 55/45 % polyester/viscose fabrics by the exhaustion process with the amounts of 1%, 2%, 3% and 4% on weight of the material. Liquor ratio was 20:1. The UV treatment was initiated at 60°C, after 10 minutes, 15 g/L Na_2SO_4 were added to the bath. 45 minutes later, 5 g/L Na_2CO_3 were added and the process continued for 90 minutes.

2.8 Application of Rayosan C

Rayosan C was applied to undyed 100% cotton, 97.5/2.5% viscose/Lycra, 50/50% polyester/cotton and 55/45 % polyester/viscose fabrics by the exhaustion process with the amounts of 1%, 2%, 3% and 4% on weight of the material. Liquor ratio was 20:1. 70 g/L Na_2SO_4 and % (2+y) Na_2CO_3 were used and the application procedure. “y” is the amount of Rayosan C. The treatment was carried out at 40°C for 50 minutes.

2.9 Application of Cibafast P and Fadex ECS

Cibafast P and Fadex ECS were applied to 100% polyester (interlock), 50/50% polyester/cotton and 55/45 % polyester/viscose fabrics by the exhaustion process with the amounts of 2%, 3% and 4% on weight of the material. Liquor ratio was 20:1. 1 g/L dispersing agent was used and the pH of the bath was set to 4.5-5. The treatment was carried out at 130°C for 45 minutes and eventually the materials were given a reduction clearing. The reduction clearing process was carried out with 2 g/L NaOH, 2 g/L hydrosulphite and 2 g/L

dispersing agent.

2.10 Dyeing and the Application of Cibafast P and Fadex ECS

100% polyester (interlock) fabric was dyed with 0.25%, 1% and 4% o.w.f Dianix Yellow S-4G in the presence of 2% o.w.f. Cibafast P or 4% o.w.f. Fadex ECS. Sample weight was 5 g for each treatment and the liquor ratio, 20:1. 1 g/L dispersing agent was added to each bath and the pH was 4.5-5.0. The “all-in” exhaustion dyeing method was used and the dyeing was commenced at 60°C, then the bath temperature was raised to 130°C at a heating rate of 2°C/min. At this temperature, the dyeing was carried out for 20-45 min. and the bath was cooled to 30°C. The dyed materials were given a reduction clearing with a bath containing 2 g/L NaOH, 2 g/L Na₂S₂O₄, 2 g/L dispersing agent. The liquor ratio was 20:1 and the treatment time was 20 min.

100% polyester (jersey) knitted fabric were also dyed with 0.05%, 0.1%, 0.5%, 1%, 2% and 3% o.w.f Dianix Yellow S-4G, Dianix Red 2BSL- FS 150 and Dianix Blue GSL 400 in the presence of 2% o.w.f. Cibafast P or 2% o.w.f. Fadex ECS. Similarly, 100% PES voile and satin woven fabrics were dyed with 1% o.w.f. Dianix Yellow S-4G, 1% o.w.f. Dianix Red 2BSL- FS 150 (C.I. Disperse Red 184) and 1% o.w.f. Dianix Blue GSL 400 (C.I. Disperse Blue 165) in the presence of the UV absorbers. Sample weight was 5 g for each treatment and the liquor ratio, 40:1. 1 g/L dispersing agent was added to each bath and the pH was 4.5-5.0. The “all-in” exhaustion dyeing method was used and the dyeing was commenced at 50°C, after 30 minutes the bath temperature was raised to 130°C at a heating rate of 1.5°C/min. At this temperature, the dyeing was carried out for 30 min. and the bath was later cooled to 30°C. The dyed materials were given a reduction clearing with a bath containing 2 g/L NaOH, 2 g/L Na₂S₂O₄, 2 g/L dispersing agent. The liquor ratio was 20:1 and the treatment time was 20 min.

2.11 Dyeing and the Application of Tinofast CEL and Rayosan C

5 g samples of 100% cotton was dyed with 0.25%, 1% and 4% o.w.f Remazol Yellow GR (DyStar) in the presence of either 4% o.w.f. Tinofast CEL or 4% o.w.f. Rayosan C. 100% viscose woven fabric was dyed with 0.25% and 1% o.w.f Remazol Yellow GR (DyStar) in the presence of either Tinofast CEL or Rayosan C. In the treatment of the viscose fabric with the UV absorbers in the dyeing bath, different concentrations of the UV absorbers (0.25%, 1%, 2%, 3% and 4% o.w.f.) were used.

Liquor ratio was 20:1. The “all-in” exhaustion dyeing was commenced at 25°C, and at a heating rate of 2°C/min the dyebath was heated up to 60°C. At 60°C, the dyeing was carried out for 60 min. and eventually the bath was cooled down to 30°C. 50 g/L sodium sulphate, 5 g/L Na₂CO₃ and 1 mL/L NaOH (38°Be) were used in the reactive dyeing. After dyeing, washings/rinsing stages and the neutralization of the material with 2-3 mL acetic acid (60%) were carried out in a conventional way.

Tinofast CEL was applied to 100% viscose at 1% to 4% o.w.f. concentration levels and 0.25% and 1% o.w.f. Remazol Yellow GR (DyStar) reactive dye was used in the dyeings. Liquor ratio was 20:1. 5 g samples were dyed by exhaustion in the presence of the UV absorber. The dyeing was commenced at 25°C, and at a heating rate of 2°C/min the dyebath was heated up to 60°C. At 60°C, the dyeing was carried out for 60 min. and eventually the bath was cooled down to 30°C. 50 g/L sodium sulphate, 5 g/L Na₂CO₃ and 1 mL/L NaOH (38°Be) were used in the reactive dyeing. After dyeing, washings/rinsing stages and the neutralization of the material with 2-3 mL acetic acid (60%) were carried out in a

conventional way.

3. RESULTS AND DISCUSSIONS

3.1 UPF of Tinofast CEL Treated Fabrics

The UPF values of Tinofast CEL treated 100% cotton, 97.5/2.5 % viscose/Lycra, 50/50 % polyester/cotton and 55/45 % polyester/viscose fabrics are given in Tables 2-5, respectively.

Table 2: UPF values of Tinofast CEL treated 100% cotton knitted fabric.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Tinofast CEL	5	5	5	25.68	16.39
1% Tinofast CEL	39	35	35	8.01	2.25
2% Tinofast CEL	61	55	50+	5.25	1.45
3% Tinofast CEL	75	69	50+	4.18	1.19
4% Tinofast CEL	83	78	50+	3.58	1.08

The UPF values of the Tinofast CEL treated cotton is increased with the increasing concentration of the UV absorber. Tinofast CEL gives “good to excellent” UV protection to 100% cotton knit, even with low concentrations.

Table 3: UPF values of Tinofast CEL treated 97.5/2.5 % viscose/Lycra knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Tinofast CEL	11	9	5	16.98	8.38
1% Tinofast CEL	72	62	50+	4.97	1.22
2% Tinofast CEL	86	85	50+	3.67	1.04
3% Tinofast CEL	114	110	50+	2.61	0.81
4% Tinofast CEL	119	112	50+	2.22	0.77

The UPF values of the Tinofast CEL treated 97.5/2.5 % viscose/Lycra is increased with the increasing concentration of the UV absorber. Tinofast CEL gives “excellent” UV protection to 97.5/2.5 % viscose/Lycra knit, and “good” protection can be achieved against UVR.

Table 4: UPF values of Tinofast CEL treated 50/50 % polyester/cotton knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Tinofast CEL	11	9	5	22.49	7.58
1% Tinofast CEL	19	17	15	12.74	4.53
2% Tinofast CEL	21	18	15	11.03	4.11
3% Tinofast CEL	30	26	25	8.31	2.87
4% Tinofast CEL	30	27	25	8.09	2.95

The UPF values of the Tinofast CEL treated 50/50 % polyester/cotton is little affected by increasing the concentration of the UV absorber from 1% to 4%. Tinofast CEL gives “good to very good” protection to this fabric.

Table 5: UPF values of Tinofast CEL treated 55/45 % polyester/viscose knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Tinofast CEL	8	8	5	26.06	10.17
1% Tinofast CEL	15	14	10	13.36	5.93
2% Tinofast CEL	16	14	10	11.73	5.65
3% Tinofast CEL	18	16	15	10.58	5.1
4% Tinofast CEL	20	18	15	9.64	4.66

The UPF values of the Tinofast CEL treated 55/45 % polyester/viscose is little affected by increasing the concentration of the UV absorber from 1% to 4% and Tinofast CEL gives “good protection” to this fabric only with high concentrations applied.

3.2 Application of Rayosan C

The UPF values of Rayosan C treated 100% cotton, 97.5/2.5 % viscose/Lycra, 50/50 % polyester/cotton and 55/45 % polyester/viscose fabrics are given in Tables 6-9, respectively.

Table 6: UPF values of Rayosan C treated 100 % cotton knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Rayosan C	6	5	5	24.52	15.32
1% Rayosan C	11	10	10	24.23	6.54
2% Rayosan C	14	14	10	23.30	4.45
3% Rayosan C	16	15	15	23.34	3.55
4% Rayosan C	19	17	15	21.47	2.87

The UPF values of the Rayosan C treated cotton is slightly increased with the increasing concentration of the UV absorber. Rayosan C only gives “good” UV protection to 100% cotton knits. The treated fabrics absorb more UVB radiation, but UVA absorption is almost kept unchanged as the concentration of the UV absorber applied to the fabric is increased.

Table 7: UPF values of Rayosan C treated 97.5/2.5 % viscose/Lycra knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Rayosan C	12	11	10	15.37	7.28
1% Rayosan C	18	17	15	15.99	3.76
2% Rayosan C	22	21	20	15.31	2.86
3% Rayosan C	24	22	20	15.24	2.59
4% Rayosan C	30	25	25	13.5	2.11

The UPF values of the Rayosan C treated 97.5/2.5 % viscose/Lycra is slightly increased with the increasing concentration of the UV absorber and Rayosan C gives “good to very good” UV protection to these fabrics. The treated fabrics absorb more UVB radiation, but UVA absorption is almost kept unchanged as the concentration of the UV absorber applied to the fabric is increased.

Table 8: UPF values of Rayosan C treated 50/50 % polyester/cotton fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Rayosan C	13	11	10	19.84	6.07
1% Rayosan C	13	12	10	20.15	5.55
2% Rayosan C	13	12	10	20.99	5.42
3% Rayosan C	14	13	10	20.75	5.24
4% Rayosan C	13	12	10	21.28	5.43

The UPF values of the Rayosan C treated 50/50 % polyester/cotton is almost unaffected with the increasing concentration of the UV absorber and Rayosan C gives “good to very good” UV protection to these fabrics.

Table 9: UPF values of Rayosan C treated 55/45 % polyester/viscose fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Rayosan C	9	8	5	24.91	9.59
1% Rayosan C	9	9	5	25.89	8.34
2% Rayosan C	10	9	5	25.81	7.06
3% Rayosan C	8	9	5	24.79	6.69
4% Rayosan C	10	10	10	25.78	6.8

The UPF values of the Rayosan C treated 55/45 % polyester/viscose is almost unaffected with the increasing concentration of the UV absorber and Rayosan C gives no UV protection properties for these fabrics.

3.3 Application of Cibafast P

The UPF values of Cibafast P treated 100 % polyester, 50/50 % polyester/cotton, 55/45 % polyester/viscose fabrics are given in Tables 10-12, respectively.

Table 10: UPF values of Cibafast P treated 100 % polyester (interlock) knitted fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Cibafast P	133	124	50+	5.25	0.44
1% Cibafast P	375	351	50+	1.61	0.21
2% Cibafast P	583	570	50+	0.93	0.15

The untreated 100% polyester interlock knit has an excellent UV protection property and the application of Cibafast P, even at small amounts, imparts UVR absorption property as the concentration of the applied UV absorber is increased.

Table 11: UPF values of Cibafast P treated 50/50 % polyester/cotton fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Cibafast P	14	13	10	21.95	5.27
1% Cibafast P	24	23	20	9.66	3.86
2% Cibafast P	28	25	25	8.09	3.31

The Cibafast P treated 50/50 % polyester/cotton knits have “good to very good” UV protection property and the application of Cibafast P, even at small amounts, imparts UVR absorption property as the concentration of the applied UV absorber is increased.

Table 12: UPF values of Cibafast P treated 55/45 % polyester/viscose fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Cibafast P	8	8	5	25.17	10.7
1% Cibafast P	12	11	10	11.94	8.43
2% Cibafast P	12	12	10	10.91	7.97

The Cibafast P treated 55/45 % polyester/viscose knits have no UV protection property and the application of Cibafast P to these materials only imparts UVR absorption property to some extent.

3.4 Application of Fadex ECS

The UPF values of Fadex ECS treated 100 % polyester, 50/50 % polyester/cotton, 55/45 % polyester/viscose fabrics are given in Tables 13-15, respectively.

Table 13: UPF values of Fadex ECS treated 100% polyester (interlock) fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Fadex ECS	146	137	50+	4.71	0.41
2% Fadex ECS	397	389	50+	1.66	0.20
3% Fadex ECS	525	488	50+	1.25	0.16
4% Fadex ECS	632	612	50+	1.01	0.13

The untreated 100% polyester interlock knit has an excellent UV protection property and the application of Fadex ECS, even at small amounts, imparts UVR absorption property as the concentration of the applied UV absorber is increased.

Table 14: UPF values of Fadex ECS treated 50/50 % polyester/cotton fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Fadex ECS	15	14	10	21.57	4.75
2% Fadex ECS	26	24	20	9.87	3.54
3% Fadex ECS	29	27	25	8.33	3.17
4% Fadex ECS	34	30	25	6.98	2.77

The Fadex ECS treated 50/50% polyester/cotton knit show “good to very good” UV protection property and the application of Fadex ECS, even at small amounts, imparts UVR absorption property as the concentration of the applied UV absorber is increased.

Table 15: UPF values of Fadex ECS treated 55/45 % polyester/viscose fabrics.

Specimen	Mean UPF	Mean UPF of the sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
0% Fadex ECS	8	8	5	24.44	10.04
2% Fadex ECS	11	11	10	11.90	8.58
3% Fadex ECS	13	12	10	10.79	7.83
4% Fadex ECS	13	12	10	10.01	7.74

The Fadex ECS treated 55/45% polyester/viscose knits have no UV protection property.

3.5 UPF Values of Simultaneously Dyed and Finished 100% PES Fabric

The UPF values of 100% PES interlock knitted fabrics dyed with a disperse dye in the presence of a UV absorbers are given in Table 16.

Table 16: UPF values of 100% PES (interlock) dyed with Dianix Yellow S-4G in the presence of Cibafast P or Fadex ECS.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	50	45	45	10.96	1.12
0% dye (blind treatment)	133	124	50+	5.25	0.44
1% Dianix Yellow S-4G	1663	1426	50+	0.13	0.05
4% Dianix Yellow S-4G	1946	1740	50+	0.08	0.04
1% Dianix Yellow S-4G + 2% Cibafast P	3463	3154	50+	0.04	0.03
4% Dianix Yellow S-4G + 2% Cibafast P	3148	2833	50+	0.04	0.03
1% Dianix Yellow S-4G + 4% Fadex ECS	3660	3364	50+	0.05	0.03
4% Dianix Yellow S-4G + 4% Fadex ECS	3134	2617	50+	0.04	0.03

100% PES jersey knitted and 100% PES woven fabrics with voile and satin structures were also simultaneously dyed and finished with the UV absorbers. Dianix Yellow S-4G, Dianix Red 2BSL-FS 150 and Dianix Blue GSL 400 disperse dyes were used in the dyeings.

The application of the UV absorbers to 100% PES knits improved the UV protection and increased the UPF values, being the highest with a dark shaded and one of the UV absorbers applied fabrics. The “shade factors” of the UV absorbers treated and dyed voile and satin fabrics were calculated in accordance with the method described in AS 4174-1994 standard and the results are given in Figure 1 and Figure 2. The shade factors are increased if the fabric is treated with one of the UV absorbers. The satin fabrics had better shade factor values compared to the voile fabrics.

Table 17: UPF values of the samples of UV absorbers treated/dyed with Dianix Yellow S-4G.

Material	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated and undyed	27	23	25	6.60	3.38
0% Yellow S-4G + 2% Fadex ECS	34	30	30	3.84	2.81
0% Yellow S-4G + 2 Cibafast P	35	32	35	3.19	2.85
0.05% Yellow S-4G + 0% UV Abs.	27	26	25	4.84	3.54
0.05% Yellow S-4G+ 2% Fadex ECS	42	38	40	2.83	2.34
0.05% Yellow S-4G + 2% Cibafast P	47	42	45	2.47	2.12
0.1% Yellow S-4G + 0% UV Abs.	32	29	30	4.06	2.92
0.1% Yellow S-4G + 2% Fadex ECS	54	49	50+	2.44	1.79
0.1% Yellow S-4G + 2% Cibafast P	68	60	50+	1.76	1.44
0.5% Yellow S-4G + 0% UV Abs.	40	36	40	2.92	2.45
0.5% YellowS-4G + 2% Fadex ECS	65	49	50+	1.80	1.51
0.5% Yellow S-4G + 2% Cibafast P	65	60	50+	1.83	1.51
1% Yellow S-4G+ 0% UV Abs.	41	37	40	2.68	2.41
1% Yellow S-4G+ 2% Fadex ECS	63	57	50+	1.70	1.58
1% Yellow S-4G + 2% Cibafast P	67	65	50+	1.68	1.45
2% Yellow S-4G + 0% UV Abs.	43	42	40	2.60	2.26
2% Yellow S-4G + 2% Fadex ECS	53	46	50+	2.07	1.85
2% Yellow S-4G + 2% Cibafast P	71	68	50+	1.54	1.38
3% Yellow S-4G + 0% UV Abs.	48	47	45	2.45	1.98
3% Yellow S-4G + 2% Fadex ECS	69	62	50+	1.60	1.41
3% Yellow S-4G + 2% Cibafast P	89	80	50+	1.21	1.11

Table 18: UPF of the samples of UV absorbers treated/dyed with Dianix Red 2BSL-FS 150.

Material	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated and undyed	27	23	25	6.60	3.38
0% Red 2BSL-FS 150 + 2% Fadex ECS	34	30	30	3.84	2.81
0% Red 2BSL-FS 150 + 2% Cibafast P	35	32	35	3.19	2.85
0.05% Red 2BSL-FS 150 + 0% UV Abs.	33	28	30	4.95	2.79
0.05% Red 2BSL-FS 150+2% Fadex ECS	49	47	45	2.88	1.98
0.05% Red 2BSL-FS 150 + 2% Cibafast P	48	45	45	2.60	2.06
0.1% Red 2BSL-FS 150 + 0% UV Abs.	45	44	45	3.70	2.03
0.1% Red 2BSL-FS 150 + 2% Fadex ECS	56	51	50+	2.55	1.71
0.05% Red 2BSL-FS 150 + 2% Cibafast P	62	55	50+	2.04	1.58
0.5% Red 2BSL-FS 150 + 0% UV Abs.	46	45	45	3.17	2.06
0.5% Red 2BSL-FS 150 + 2% Fadex ECS	61	51	50+	2.11	1.59
0.5% Red 2BSL-FS 150 + 2% Cibafast P	58	55	50+	2.21	1.66
1% Red 2BSL-FS 150 + 0% UV Abs.	46	44	45	2.81	2.12
1% Red 2BSL-FS 150 + 2% Fadex ECS	53	51	50+	2.38	1.85

1% Red 2BSL-FS 150 + 2% Cibafast P	75	65	50+	1.74	1.27
2% Red 2BSL-FS 150 + 0% UV Abs.	41	41	40	2.84	2.39
2% Red 2BSL-FS 150 + 2% Fadex ECS	47	38	45	2.43	2.14
2% Red 2BSL-FS 150 + 2% Cibafast P	64	56	50+	1.84	1.53
3% Red 2BSL-FS 150 + 0% UV Abs.	46	43	45	2.68	2.10
3% Red 2BSL-FS 150 + 2% Fadex ECS	69	63	50+	1.72	1.42
3% Red 2BSL-FS 150 + 2% Cibafast P	62	62	50+	1.89	1.56

Table 19: UPF values of the samples of UV absorbers treated/dyed with Dianix Blue GSL 400.

Material	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated and undyed	27	23	25	6.60	3.38
0% Blue GSL 400 + 2% Fadex ECS	34	30	30	3.84	2.81
0% Blue GSL 400 + 2% Cibafast P	35	32	35	3.19	2.85
0.05% Blue GSL 400 + 0% UV Abs.	33	25	30	4.58	2.83
0.05% Blue GSL 400 + 2% Fadex ECS	56	53	50+	2.52	1.71
0.05% Blue GSL 400 + 2% Cibafast P	51	49	50+	2.53	1.90
0.1% Blue GSL 400 + 0% UV Abs.	46	44	45	3.44	2.01
0.1% Blue GSL 400 + 2% Fadex ECS	53	49	50+	2.62	1.81
0.1% Blue GSL 400 + 2% Cibafast P	78	71	50+	1.75	1.24
0.5% Blue GSL 400 + 0% UV Abs.	58	53	50+	2.36	1.63
0.5% Blue GSL 400 + 2% Fadex ECS	69	58	50+	1.87	1.40
0.5% Blue GSL 400 + 2% Cibafast P	70	63	50+	1.76	1.38
1% Blue GSL 400 + 0% UV Abs.	60	53	50+	2.18	1.57
1% Blue GSL 400 + 2% Fadex ECS	72	70	50+	1.76	1.34
1% Blue GSL 400 + 2% Cibafast P	83	74	50+	1.46	1.17
2% Blue GSL 400 + 0% UV Abs.	87	65	50+	1.56	1.09
2% Blue GSL 400 + 2% Fadex ECS	95	90	50+	1.31	1.02
2% Blue GSL 400 + 2% Cibafast P	102	89	50+	1.14	0.98

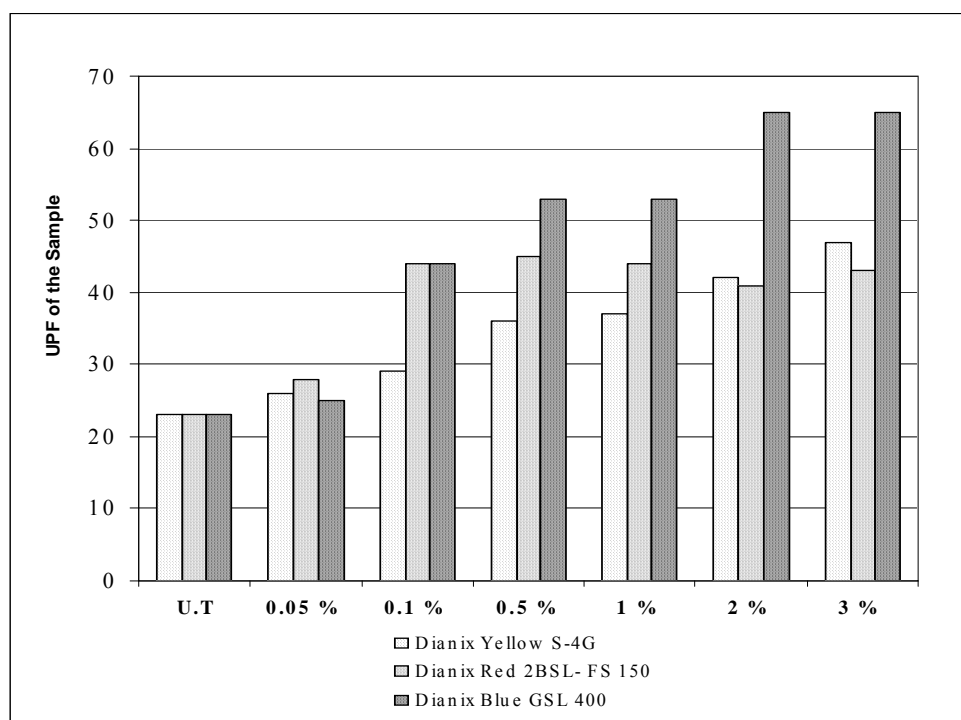


Figure 1: The UPF values of 100% PES knitted fabrics dyed with Dianix Yellow S-4G, Dianix Red 2BSL-FS 150 and Dianix Blue GSL 400.

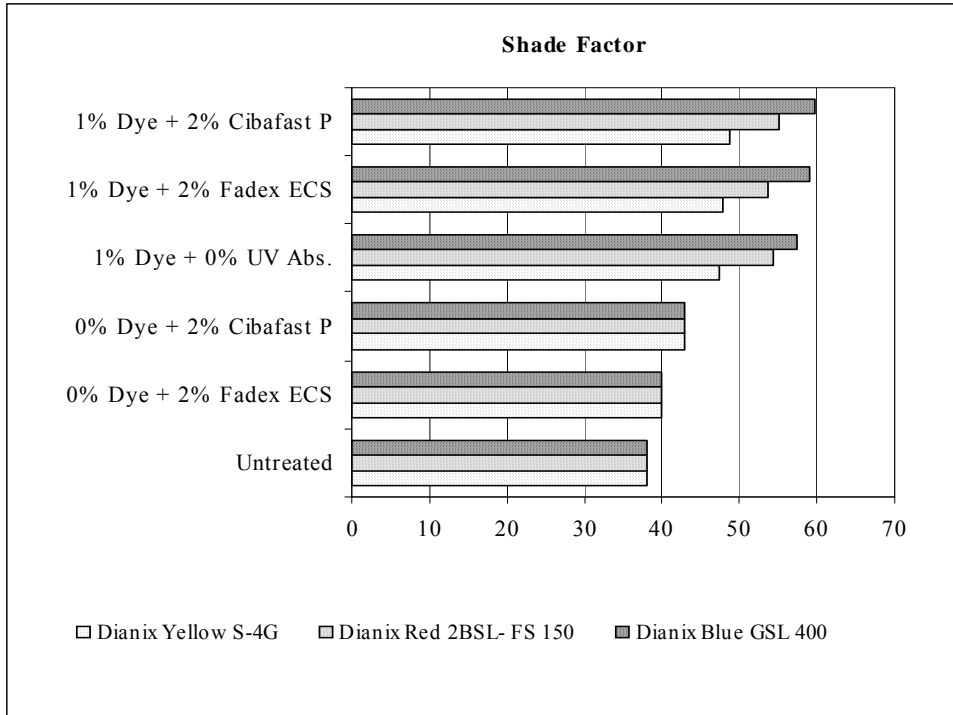


Figure 2: The Shade Factors of the dyed and UV absorber treated 100% PES voile fabrics.

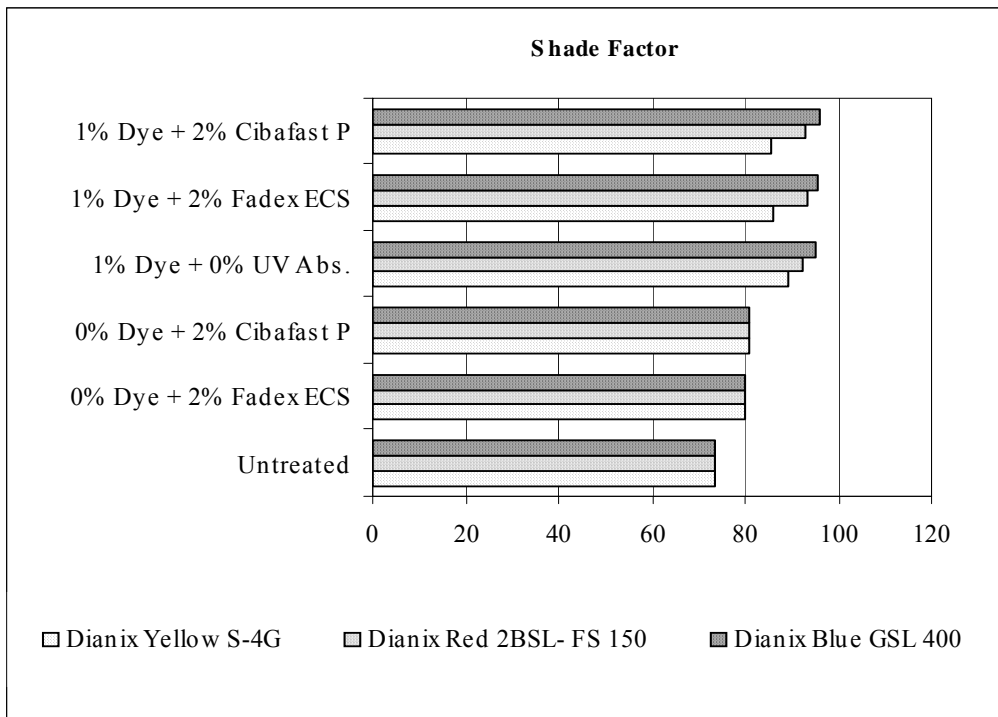


Figure 3: The Shade Factors of the dyed and UV absorber treated 100% PES satin fabrics.

All the treatments/dyeings were carried out several times and the process was found “repeatable”. Colour fastness tests were carried out with the treated/dyed samples and the wash fastness test results were found “good” as being “4” to “4-5” Grey Scale ratings for both the knitted fabrics and woven fabrics. The staining results of 1% dyed and UV absorber treated woven fabrics were in the range of “3” to “4-5”. The sublimation colour fastness tests were also carried out and found “good” for the treated/dyed fabrics with a few exceptions.

The crocking fastnesses for all the materials were found “excellent” as being “4-5” to “5”.

3.6 UPF Values of Simultaneously Dyed and Finished 100% cotton fabric

The UPF values from the applications of Tinofast CEL and Rayosan C to 100% cotton are given in Tables 20 and 21.

Table 20: UPF values of 100% cotton dyed with Remazol Yellow GR in the presence of Tinofast CEL.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	5	5	5	25.62	16.23
0% dye (blind treatment)	5	5	5	25.68	16.39
0.25% Remazol Yellow GR	11	9	5	7.44	8.83
1% Remazol Yellow GR	24	21	20	2.52	3.97
4% Remazol Yellow GR	47	36	35	1.57	2.2
0.25% Remazol Yellow GR + 4% Tinofast CEL	105	89	50+	2.06	0.87
1% Remazol Yellow GR + 4% Tinofast CEL	124	113	50+	1.22	0.76
4% Remazol Yellow GR + 4% Tinofast CEL	167	154	50+	0.67	0.58

Table 21: UPF values of 100% cotton dyed with Remazol Yellow GR in the presence of Rayosan C.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	5	5	5	25.62	16.23
0% dye (blind treatment)	5	5	5	25.68	16.39
0.25% Remazol Yellow GR	11	9	5	7.44	8.83
1% Remazol Yellow GR	24	21	20	2.52	3.97
4% Remazol Yellow GR	47	36	35	1.57	2.2
0.25% Remazol Yellow GR + 4% Rayosan C	18	16	15	2.06	0.87
1% Remazol Yellow GR + 4% Rayosan C	33	27	25	1.22	0.76
4% Remazol Yellow GR + 4% Rayosan C	66	58	50+	0.67	0.58

3.7 UPF Values of Simultaneously Dyed and Finished 100% Viscose Fabric

100% viscose fabric was dyed with 0.25% and 1% o.w.f. dye concentrations in the presence of one of the UV absorbers, namely Tinofast CEL and Rayosan C. The UPF values were given in Tables 22-25, respectively.

Table 22: UPF values of 100% viscose dyed with 0.25% Remazol Yellow GR in the presence of Tinofast CEL.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	3	3	5	37.44	29.56
0.25% Remazol Yellow GR	6	6	5	13.00	15.03
0.25% Remazol Yellow GR + 1% Tinofast CEL	15	13	10	10.42	7.32
0.25% Remazol Yellow GR + 2% Tinofast CEL	19	18	15	8.39	5.37
0.25% Remazol Yellow GR + 3% Tinofast CEL	21	21	20	7.14	4.50
0.25% Remazol Yellow GR + 4% Tinofast CEL	26	24	20	6.59	3.94

Table 23: UPF values of 100% viscose dyed with 1% Remazol Yellow GR in the presence of Tinofast CEL.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	3	3	5	37.44	29.56
1% Remazol Yellow GR	10	12	10	5.84	8.32
1% Remazol Yellow GR + 1% Tinofast CEL	19	17	15	5.97	5.57
1% Remazol Yellow GR + 2% Tinofast CEL	27	26	25	4.49	3.72
1% Remazol Yellow GR + 3% Tinofast CEL	23	22	20	5.44	4.50
1% Remazol Yellow GR + 4% Tinofast CEL	21	20	20	6.00	4.92

Table 24: UPF values of 100% viscose dyed with 0.25% Remazol Yellow GR in the presence of Rayosan C.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	3	3	5	37.44	29.56
0.25% Remazol Yellow GR	5	5	5	18.56	20.84
0.25% Remazol Yellow GR + 1% Rayosan C	7	6	5	18.14	13.34
0.25% Remazol Yellow GR + 2% Rayosan C	7	8	5	15.32	9.46
0.25% Remazol Yellow GR + 3% Rayosan C	7	8	5	17.82	9.56
0.25% Remazol Yellow GR + 4% Rayosan C	9	10	10	14.01	7.95

Table 25: UPF values of 100% viscose dyed with 1% Remazol Yellow GR in the presence of Rayosan C.

Sample	Mean UPF	Mean UPF of the Sample	Rated UPF	UVA _{AV} (%)	UVB _{AV} (%)
Untreated	3	3	5	37.44	29.56
1% Remazol Yellow GR	7	7	5	10.13	13.24
1% Remazol Yellow GR + 1% Rayosan C	7	7	5	10.79	13.57
1% Remazol Yellow GR + 2% Rayosan C	8	9	5	8.28	9.84
1% Remazol Yellow GR + 3% Rayosan C	12	13	10	7.42	6.57
1% Remazol Yellow GR + 4% Rayosan C	13	13	10	6.45	6.68

4. CONCLUSIONS

In the experimental works⁴⁻⁷ reported in this paper, four commercially available UV absorbers were applied to knitted or woven fabrics with different fibre contents and only the UPF values are taken into account to evaluate the efficiency of the UV absorbers. The applications of the UV absorbers have generally given the UV protection to the materials and imparted “good to excellent” UV protection. The dye concentration is also effective and the UPF values for each UV absorber treated fabric are increased as the concentration is increased. In general, the UV absorbers used in the research works did not impair the colour fastness and the staining fastness properties of the fabrics.

Recently, the simultaneous dyeing and multiple finishing of polyester yarns were studied and the combinations of an antibacterial finish, an UV absorber and a flame retardant finish were applied to the materials¹. Another research work was carried out on the application of reactive type UV absorbers to cationized cellulose². The synergistic effects of the UV absorbers on the polyester/cellulosic blends were also investigated³.

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HYBRID ORGANIC NANOPARTICLES FOR FUNCTIONAL COATING APPLICATIONS

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Keywords: nanoparticles, imidization, coating, styrene-maleimide copolymer, oil

Abstract: *The application of ecological and functional coatings for controlling surface wettability and barrier properties has become a challenging discipline, and was achieved by using bio-renewable resources in combination with recent nanotechnology. hybrid organic nanoparticles were synthesized by partial imidization of poly(styrene-maleic) anhydride in the presence of various bio-renewable oil types, such as palm-oil, soy-oil, corn-oil, rapeseed-oil or castor-oil. The successful synthesis of hybrid organic nanoparticles was obtained by tuning reaction parameters and compositions, for encapsulating various vegetable oils into organic nanoparticles containing up to 70 wt.-% of oil. The particles have a z-average diameter of about 146 nm (in stable water-borne dispersion) and 35 to 50 nm (adsorbed on paper surfaces).*

The functionality of the nanomaterials in increasing hydrophobicity and water repellency of porous substrates is significant, depending on the type and content of encapsulated oil or ratio of reagentia. While progressively increasing the oil content up to a maximum of 70 wt.-% of the coating composition, the water adsorption decreases while the contact angle increases at a constant coating weight. On the other hand, the nanoparticles are also compatible with common synthetic binders to provide a continuous and protective film.

The SMI/oil nanocomposites form a more continuous film than the pure SMI nanoparticles deposited onto paper substrates, leading to a significant protection and serving as an effective water-repellent barrier coating. Surface treatment of tissues with the organic nanoparticles provides super-hydrophobic textile surfaces, which are characterized by a static contact angle of 148° and spontaneous rolling-off the water droplets from the surface.

1. INTRODUCTION

The recent developments in nanotechnology have caused a tremendous range of exciting applications and new research domains, covering multiple disciplines from biology, physics, electronics, and chemistry to textile engineering. The functionalization of textile substrates at the nanometer scale made it possible to increase their performance. Amongst various technologies, more general and fundamental questions arise on the compatibility of textile surfaces and interfaces, considering the interactions with environments and other material phases in composite structures. Mainly for natural-fiber based textiles, including papers and cellulose derivatives, there is a huge potential for tailoring the interfacial properties by nanoscale engineering. The combination of cellulose (as one of the broadest available renewable and recyclable resources) with bio-inspired or bio-renewable polymer resources offers great potential for improving their properties. The intrinsic hydrophilicity and porosity

of cellulose- and natural-fiber based materials, however, make them sensitive to water uptake and poor barrier resistance. This limitation should be covered by application of hydrophobic materials such as synthetic polymer layers or paraffin waxes by means of extrusion coating or lamination, which reduce the recyclability and repulpability of original paper substrates.

At present, the hydrophobicity of paper surfaces is often modified by techniques including internal and/or surface sizing additives¹, or coatings with modified starches², biopolymers³, styrene-acrylate core-shell latexes⁴ or acrylate micro latexes⁵. The nanoscale modifications presented within this contribution will allow to tune the properties of cellulose substrates in terms of (super) hydrophobicity, printability, barrier performance, friction and adhesion at the nanoscale. Organic nanoparticles were synthesized by an imidization reaction of styrene-maleic anhydride (SMA) copolymers with ammonium hydroxide and a maximum of 70 wt.-% vegetable oil (e.g. palm-, soy-, castor-, or sun-flower oil), obtaining a stable aqueous dispersion with 50 wt.-% solid content^{6,7}. Due to the reactivity of the maleic anhydride groups and versatility of the reaction parameters, the obtained nanoparticles offer an ideal platform for surface functionalization of fibers.

2. MATERIALS AND METHODS

2. 1. Materials and synthesis

Partially imidized nanoparticles of poly (styrene-maleimide) or SMI were synthesized by imidization of different types of poly(styrene-maleic anhydride) or SMA copolymers. SMA, dispersed in water was charged with an equivalent amount of ammonium hydroxide such that the molar ratio of maleic anhydride to ammonium hydroxide was 1:1.01. The reaction mixture was heated up to 160°C and the reaction pressure increased to 6 bar. The viscosity profile was monitored as the electric power needed to drive the stirrer at a constant speed of 50 rpm. As the reaction mixture attained 100 to 120°C, the viscosity increased significantly through gel formation. The viscosity suddenly dropped after a reaction time of approx. 5 hours indicating the formation of nanoparticles. After 6 hours reaction time, the reactor was cooled down to room temperature and partially imidized nanoparticles were obtained in stable aqueous dispersions.

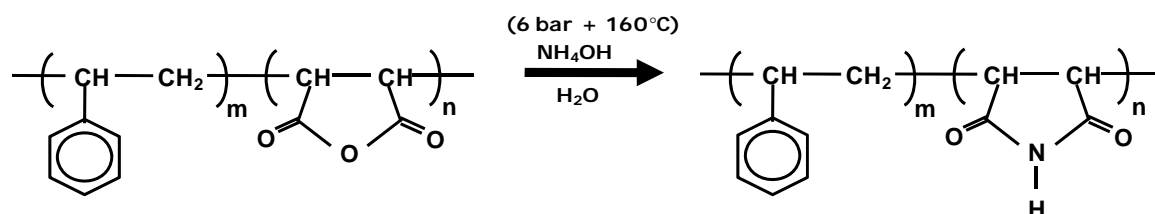


Figure 1. Chemical synthesis of styrene-maleimide (SMI) nanoparticles

The imidization reaction of SMA into styrene-maleimide (SMI) nanoparticles according to Figure 1, might serve as a basic process for production of organic nanoparticles and nanocomposites.

As such, SMI nanoparticles were obtained from SMA copolymers with different mol-% maleic anhydride (MA), as measured by ¹H-NMR measurements and different molecular weight (MW) as summarized in Table 1. The mol% of imide was analyzed by Raman measurements and the corresponding glass temperature T_g was obtained by DSC measurements.

	Mol -% MA	MW (g/mol)	T _g (°C)	mol -% imide
SMI-26	28	80000	180	20.0
SMI-28	30	65000	190	25.0
SMI-33	35	30000	194	29.4
SMI-34	37	80000	201	32.6

Table 1. Organic nanoparticle types

The resulting imidization of the SMA-copolymers is represented in figure 2. These results are a confirmation of the ¹³C-NMR measurements and the used SMA-copolymers seemed to be composed of two block-copolymers, one which contained 50 mol% of maleic anhydride (alternating copolymer) and the second one containing about 10 mol% of maleic anhydride (the limit after heat treatment).

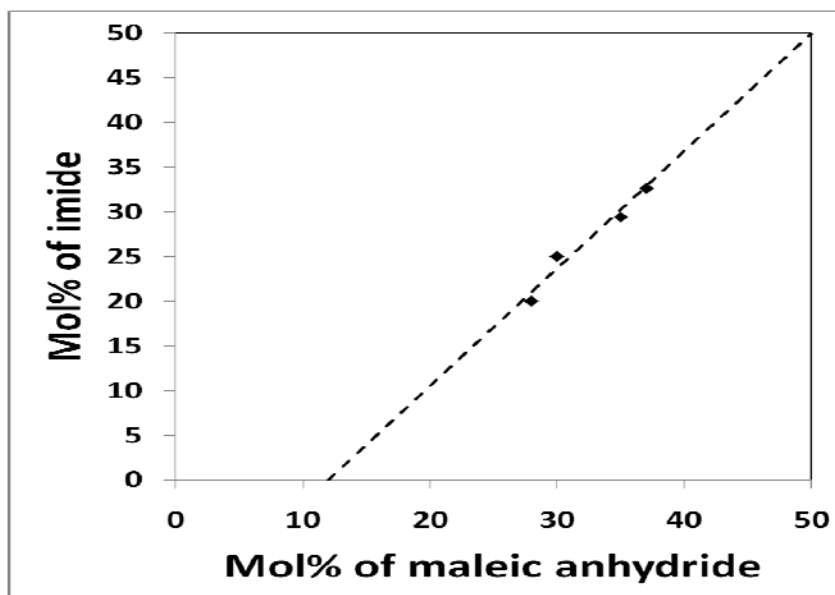


Figure 2: The resulting mol% of imide after the imidization reaction as function of the starting mol% of maleic anhydride in the SMA-copolymers.

Secondly, the imidization of SMA was done in the presence of bio-renewable oils (palm-oil, Cargill USA) in order to formulate nanocomposites based on the SMI nanoparticles. The reaction in the presence of 70 wt.-% oil was done with different ratios of MA to ammonium hydroxide. Finally, the obtained nanocomposites were analyzed and mixed into a conventional latex coating formulation.

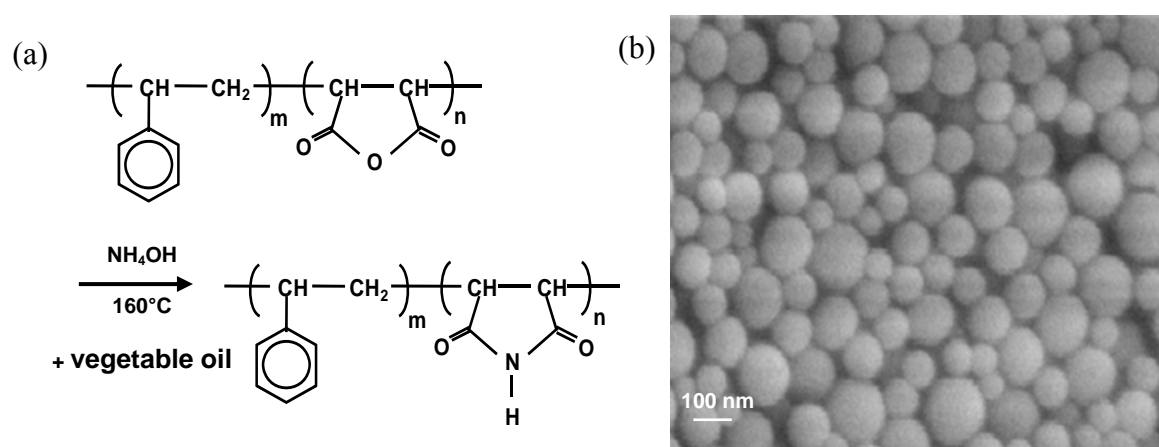


Figure 3. Styrene-maleimide nanoparticles, (a) chemical synthesis route, (b) morphology

Homogeneous and stable aqueous dispersions were obtained with a maximum solid content of 50wt%. The phase-contrast images show that the particles form a nanocomposite containing two phases, likely containing organics and oil as represented in figure 4. Further results are given in table 2.

Ratio NH ₃ /MA	T _g (°C)	Effective mol% of MA	Mol% MA in oil
1.01	155	19	9
1.30	165	23	5
1.50	172	25	3

Table 2: Glass transition temperature and resulting effective mol% MA of copolymers after imidization in the presence of oil

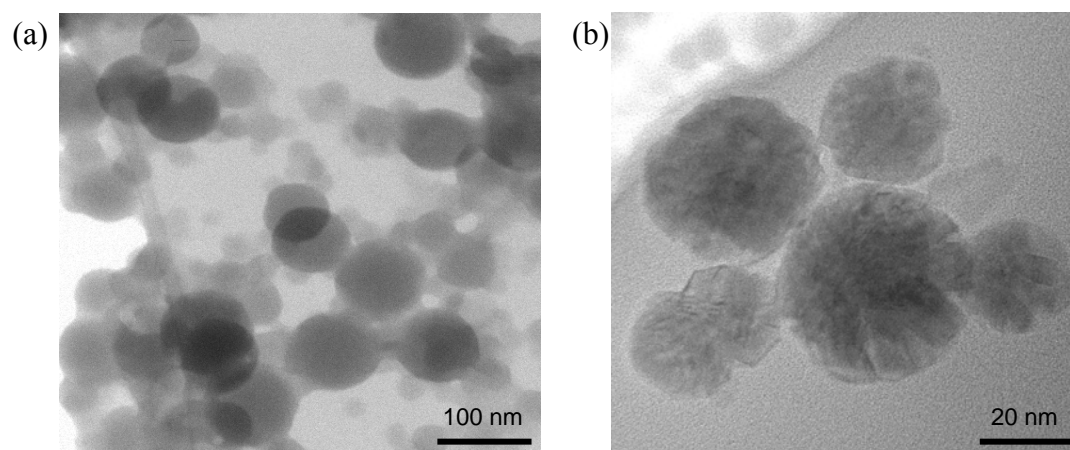


Figure 4. Transmission electron microscopy of (a) SMI nanoparticles, (b) SMI/oil nanoparticles

These results can be explained by the fact that a part of the block-copolymers containing 50 mol% of maleic anhydride (alternating copolymers) were reacting with the oil and remaining probably in the oil phase. Thus, the successful synthesis of hybrid organic nanoparticles was obtained by tuning the reaction parameters and compositions for encapsulating various

vegetable oils into organic nanoparticles containing up to 70 wt% of oil. Chemical binding between the oil and polymer phase was also spectroscopically observed and confirmed by the variation of the glass transition temperature as function of the molar ratio ammonium hydroxide/maleic anhydride. The transmission electron micrograph of the pure-and oil-filled nanoparticles (Fig. 4) confirm the existence of 80 to 100 nm spherical nanostructures (pure SMI) or 20 to 50 nm spherical structures (SMI/oil) in dry state.

When nanoparticles were synthesized in the presence of oils, the presence of an oil-rich phase around the circumference of the polymer-rich nanoparticle phase was observed. This suggests that the oil is bound to the polymer phase, while it is partly encapsulated and partly pointing outwards of the polymer structure. The polymer phase effectively serves as a carrier for the oil-phase and controls the position of the oil at its outer surface. It is important that some of the oil is presented at the outer-surface of the nanostructures, as it effectively controls the surface properties. For some products, however, not all the oil was effectively coupled to the polymer and presence of free oil should be prevented by adapting the reaction parameters.

2. 2. Characterization

In this first range of experiments, we were interested in observing the morphology of the nanocomposites and identifying the possibility to serve as barrier coating materials. Therefore, the nanoparticles were coated from aqueous dispersion onto a standard grade of paper, using a laboratory bar-coater. Observations were made by scanning electron microscopy (Philips FEI XL30 SEM) and AFM measurements in tapping mode (PicoScan 2500 with PicoSPM II Controller), using a silicon probe of $k = 40 \text{ N/m}$ and 300 kHz resonant frequency. The hydrophobicity of nanocomposite coatings was evaluated by static water contact angles.

3. RESULTS: SMI-BASED NANOCOMPOSITES

3. 1. Pure SMI nanoparticles

A scanning electron micrograph of the nanoparticles (Figure 5a) and an atomic force microscopic image of a dispersion coated layer onto paper substrates (Figure 5b) confirm the existence of 100 nm spherical nanostructures. Due to the high glass transition temperature of the nanoparticles ($T_g > 180^\circ\text{C}$), they do not form a continuous polymer film after drying, but they rather agglomerate into microdomain structures. The coatings favourably provide good printing properties and surface hydrophobicity (contact angles of 120 to 150° depending on the SMI-type), but are unfavourable to function as water-repellent barrier coatings.

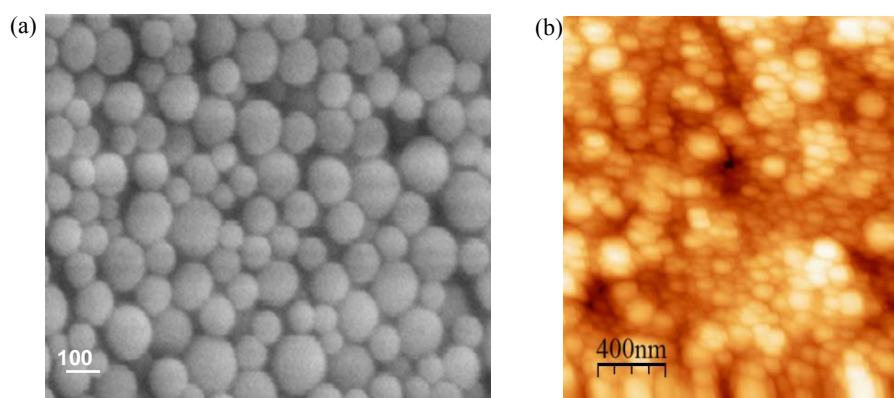


Figure 5. Pure SMI nanoparticles, (a) SEM image, (b) AFM height scan of coating on paper.

3. 2. SMI/palm oil nanocomposites

After the synthesis of SMI nanoparticles in the presence of palm oil, homogeneous and stable aqueous dispersions were obtained with a maximum solid content of 50 wt.-%. An AFM height scan of the nanoparticles (Figure 6a) indicates sizes of around 40 to 60 nm, and the phase-contrast image (Figure 6b) clearly shows that the particles form a nanocomposite containing two different phases, likely containing organics and oil. The SMI/palm oil nanocomposites form a more continuous film than the pure SMI nanoparticles deposited onto paper substrates, leading to a significant protection and serving as an effective water-repellent barrier coating.

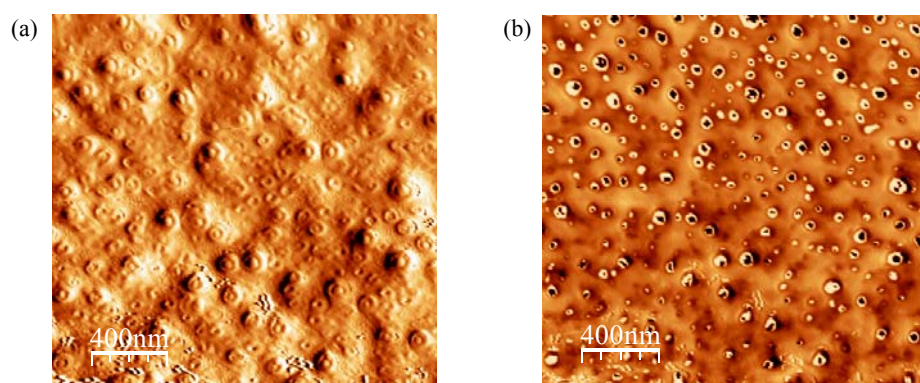


Figure 6. SMI/palm oil nanocomposites, (a) AFM height scan, (b) AFM phase scan.

3.3 Adhesion

The good interaction of organic nanoparticles with fibrous substrates (and also cohesion in the coating itself) is observed by low amount of worn coating after a simple sliding test. The good interaction between the imidized nanoparticles and cellulose fibers is clearly governed by hydrogen bridge formation between the imide-functional groups and the hydroxyl-functional groups at the cellulose substrate, as confirmed by a detail of the Raman spectra in the C-OH absorption band region (Figure 7). Cohesion between the particles and adhesion to the substrate are quite strong. No nano-particles were released upon friction and the measured roughness of surfaces was the same before and after the friction tests.

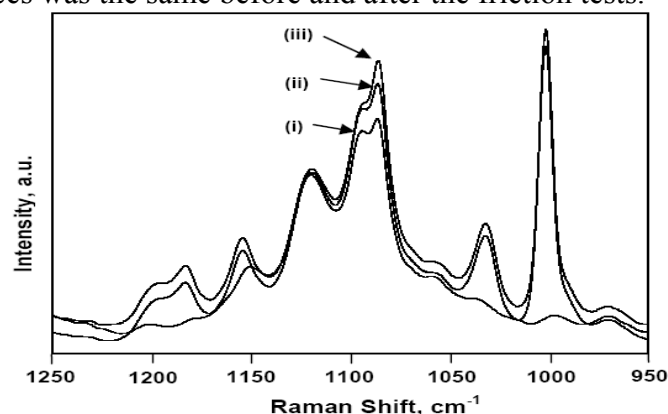


Figure 7. Detail of Raman spectra for (i) cellulose, (ii) and (iii) adsorbed organic nanoparticles.

4. CREATION OF WATER-REPELLENT CELLULOSE SURFACES

The microscale morphology of SMI and SMI/oil nanoparticle coatings onto paper substrates was studied by scanning electron microscopy and the nanoscale structures were visualized by atomic force microscopy (figure 8). Due to the high glass transition temperature of the nanoparticles, they do not form a continuous polymer film but agglomerate into a microdomain structured coating after drying. The micro-to-nanostructured coating

morphology is favourable for increasing the surface hydrophobicity and improving the printing characteristics. The oil-filled nanoparticles form a more continuous surface coating that is favorable for improving the barrier properties (e.g. water-repellence).

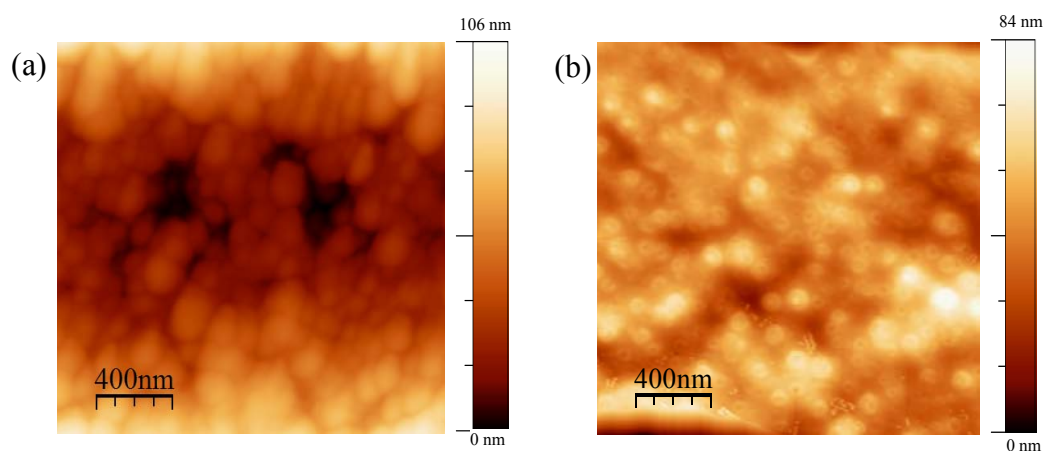


Figure 8. Atomic force microscopy of papers coated with (a) SMI, (b) SMI/oil nanoparticles.

After deposition, the thermal stability of the nanoparticle coatings was evaluated by curing the coatings at different temperatures between 60 and 250°C in a circulating hot-air oven. The pure SMI nanoparticles have good thermal stability with a glass transition temperature of 180 to 210°C, depending on the composition. The SMI/oil nanoparticles have somewhat lower glass transition temperatures of 155 to 172°C (Table 2) and are capable of thermally controlled oil-release upon heating, creating a stable oil film at the surface.

Static contact angle measurements were taken from water droplets in contact with the surface during 20 sec. For uncoated paper, the water obviously adsorbs easily into the substrate. For coated papers, the water contact angle and drop volume remains stable over the testing time. The contact angles are significantly higher for coated than for uncoated papers, and depend on further thermal treatments (Table 3): a maximum value occurs after thermal curing at 135°C. Unlike static contact angles (θ_{stat}), the dynamic contact angles (advancing θ_{adv} , and receding θ_{rec}) and contact angle hysteresis ($\Delta\theta = \theta_{adv} - \theta_{rec}$) are more closely related to the surface chemistry and topography. The dynamic water contact angles are measured over longer sampling times than static contact angles and are more sensitive to local surface roughness, surface chemistry and water absorption by the substrate.

	Mol -% MA	MW (g/mol)	Θ_s (°)	mol -% imide	θ_a (°)	θ_r (°)
SMI-26	28	80000	102	20.0	120	22
SMI-28	30	65000	120	25.0	127	31
SMI-33	35	30000	118	29.4	128	26
SMI-34	37	80000	124	32.6	137	38

Table 3: Coating characteristics of paper with SMI nanoparticles

It has been observed that further chemical reaction upon thermal curing is favourable for enhancing the surface hydrophobicity. Generally, the contact angle increases at higher degrees of imidization, which is controlled by the copolymer composition and reaction conditions. As such, a maximum contact angle of 150° can be obtained for SMI with 49 %

imide groups relatively to the styrene moieties (almost 97 % imidization). In addition, the hydrophobicity improves for the SMI/oil nanoparticle coatings that additionally provide good oleophobicity. The water repellency is determined from a Cobb-test, which is a standard measuring tool in paper industry. A water sample was in contact with a given area of the coated paper surface for 2 minutes and the amount of absorbed water is calculated by weighting the samples before and after the test. The water adsorption for uncoated paper (90 g/m²) reduces for SMI-coated paper (38 g/m²) and is the lowest for SMI/oil-coated papers, with values of 27 g/m² for 60wt%SMI/40wt% PO, 18 g/m² for 50wt% SMI/50wt% PO, 14 g/m² for 40wt% SMI/60wt% PO and 6 g/m² for 30wt% SMI/ 70wt% PO.

5. CREATION OF SUPER-HYDROPHOBIC CELLULOSE SURFACES

The creation of superhydrophobic textile structures, in general, is important for protecting fibers against water adsorption. Especially moisture-sensitive materials such as polyamide fibers may be protected against moisture and water adsorption, thereby retaining their dimensional stability or mechanical properties under variable humidity. As the nanoparticles do not form a continuous film upon drying, the coating layer keeps certain porosity. The open structure of the coating may be suitable for increasing the specific surface area and semi-permeable properties. It has been observed that there is good adhesion between the nanoparticles and several textile materials, which is mainly attributed to the presence of hydroxyl groups and formation of hydrogen bonds between the substrate and the individual nanoparticles. After coating tissues with SMI-based nanoparticles, the surfaces render self-cleaning characteristics, which are confirmed by the following contact angle data being in the super-hydrophobic range: $\theta_{\text{stat}} = 148^\circ$, $\theta_{\text{adv}} = 160^\circ$, and $\theta_{\text{rec}} = 80^\circ$. These may originate from the original roughness profiles of the fibers in combination with the decoration of the fibers with nanoparticles, as effectively illustrated by a height image from atomic force microscopy located near a fiber.

The self-cleaning properties of the nanoparticle-decorated tissues were observed from water droplets that are placed onto an inclined tissue surface. The droplet volume was progressively increased from 2 to 16 μl . The water droplet does not penetrate into the surface and remains stable onto the substrate, with a large advancing contact angle of about 150° . When the drop volume becomes too large (16 μl), the water spontaneously flows off the surface without leaving any trace behind and simultaneously removing dust from the substrate. This is an effective illustration of the self-cleaning tissue properties, created with organic nano-particle coatings.

6. SMI/STYRENE ACRYLATE NANOCOMPOSITES

The SMI nanoparticles can be combined in coatings with different weight-percentages of an organic binder component, in order to form more homogeneous barrier coatings (Figure 10). Already small weight percentages (10 %) of the nanoparticles seem to significantly improve the hydrophobicity and water repellency of common styrene-acrylate coatings.

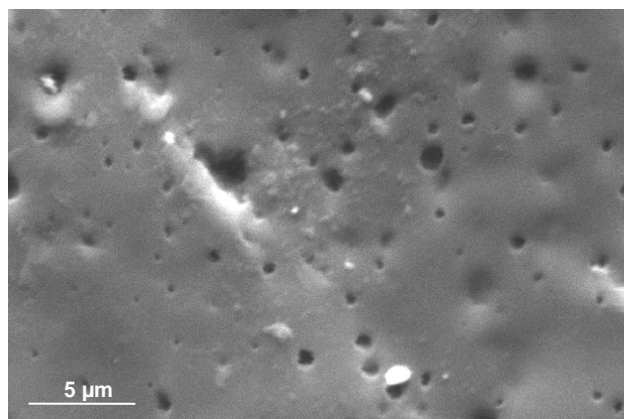


Fig. 10. SMI nanoparticles mixed into styrene/acrylate coating for nanocomposite latex coatings

7. CONCLUSIONS

Organic nanoparticles obtained by an imidization reaction of poly(styrene-maleic anhydride) under pure conditions can be applied as a top-coating onto cellulosic substrates, in order to improve the surface hydrophobicity. The nanoparticles form a micro-domain coating with water contact angles remaining stable in time and maximum hydrophobicity after additional thermal treatments at 135°C. Successful synthesis by tuning reaction parameters and compositions for encapsulating various vegetable oils into organic nanoparticles containing up to 70 wt.-% of oil was obtained. Chemical binding between the oil and polymer phase was observed and effective presentation of some oil at the outer particle surfaces was demonstrated. The particles have a z-average diameter of about 146 nm (in stable water-borne dispersion) and 35 to 50 nm (adsorbed on paper surfaces). The functionality of the nanomaterials in increasing hydrophobicity and water repellency of porous substrates is significant, depending on the type and content of encapsulated oil or ratio of reagentia. Surface treatment of tissues with the organic nanoparticles provides super-hydrophobic textile surfaces, which are characterized by a static contact angle of 148° and spontaneous rolling-off the water droplets from the surface.

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3D SCANNING TECHNOLOGY - PRESENT AND FUTURE FOR THE ROMANIAN GARMENT INDUSTRY

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Keywords: 3D Scanner, size survey, body dimensions, body type, standard, automatic pattern design.

Abstract: *The paper presents the results of using 3D scanning technology in the anthropometric survey conducted in Romania for the adult population aged 20-64 years and the future possibilities of its exploitation.*

In fashion design anthropometric data is the basis for determining the size and body type. Statistical analysis of primary survey data led to the development of two national size systems standards used in the design and manufacturing of clothing by garment industry: SR 13544- Clothing. Men's Body Measurement and Garment Sizes and SR 13545- Clothing. Women's Body Measurement and Garment Sizes. SR 13544 presents the standardized body height and Standardized variants of the Chest girth, respectively Waist girth, for the men body types and SR 13545 presents standardized body height and Standardized variants of the Chest girth, respectively Waist girth, for the men body types.

In the future, 3D scanning technology will make possible the operation and management of customer needs and preferences, the development of sophisticated CAD systems, the solutions for achieving virtual prototyping and flexible manufacturing systems and logistics oriented customer intelligence.

Internet based communication systems for manufacturers, distributors and users will allow manufacturers of textile and garment production to develop successful operations of mass customized manufacturing system comparable with custom manufacturing.

1. INTRODUCTION

This paper presents the results of the latest technology for measuring the human body 3D scanning in order to obtain anthropometric parameters and possibilities of their exploitation by inter and multidisciplinary collaboration.

The clothing items are high added-value products, and the body-size standards are crucial for the clothing design. These standards allow the producers to design their clothing sizes and models, taking into account the variability of the anthropometric parameters, forecast their sales per different clothing sizes, and settle, as a result, their production volume, schedule and control.

For this purpose, each country built its own national anthropometric databank needed for setting the sizes both for the garment standards, and for adapting the furnishing objects in

their private or professional space. The national anthropometric databanks built up to 1999 were based on measurements in contact with the subject and the use of anthropometric specific measuring tools. Advanced and integrated technologies, such as the optical measurement, the electronic signal and data digital processing, the computer software and hardware, propelled the traditional 2D measurement of the anthropometric data towards a new trend – the use of a 3D body scanning technique for the anthropometric data achievement.

The anthropometric data achieved by scanning have the potential to offer new insights for issues related to clothing dimensioning and fitting, the more the clothing industry from Romania has not been successful in the last 20 years in up-dating the anthropometric data.

In the future 3D Body Scanner technology promises to revolutionize the research and the way the clothing item will be manufactured and sold. It can be used for individual measurements necessary for tailoring clothing, without trial, allowing the anthropo – morphologic assessment of the client, the customized design according to the psychomorphologic profile of the client. Data obtained are used to automatically generate personalized patterns which are based on a greater number of dimensional characteristics taken from the actual body.¹ Increasing consumer demand for personalized clothing can be satisfied by using 3D scanning technology.

2. EXPERIMENTATION

3D scanning system used in Romania for obtaining anthropometric data is a mobile system, effective for the series measures, which consists of a 3D body scanner, Vitus Smart XXL², very precise and modular software, ScanWorx³, Anthroscan Professional⁴, XFIT Army ScanDB⁵.

Anthropometric survey for adult population, in Romania, was carried out according to the latest census data on the total adult population (male and female). Therefore, to achieve a representative selection, the following criteria were taken into account:

- The periodical stages of the calendar age, depending on the morphologic development stages: to settle the dimensional typology of the adult population, subjects from all the age groups (20 to 64 years old) were included per age groups, as follows: 20÷29 years old, 30÷39 years old, 40÷49 years old, and 50÷65 years old.
- Each of the above mentioned age groups can be found in the same percentage as in the general community, in conformity with the data obtained in the most recent census on the bases of which the total adult population is known (female and male) aged 20÷ 64 years;
- In the selection, subjects belonging to different social-professional groups were included.
- When conceiving the selection, peculiarities and morphologic variability of the population per geographical areas were also considered, as the investigation was carried out in some representative regions – Moldova, Transylvania, Dobrogea, and Muntenia-Oltenia.

Although the larger the test group, the higher the accuracy of the information about the general population, for economical reasons, this was limited to a certain extent.

The result of anthropometric survey was a database with primary information, which takes over 150 body sizes for each of the subjects. For each person measured a protocol where all the body dimensions are given and visualized is generated.

3. RESULTS

The primary data achieved within the anthropometric investigation were subject in turn to one-dimensional statistical processing, in which each of the anthropometric sizes is

considered stochastic variable, and the individual values registered for this are replaced by the synthetic values characteristic to the entire selection. These values acquire what is typical for the variable under study, providing information on the level of distribution these individual values have against the typical (average) ones, and allow us to broaden our inferences to the entire population sample.

Statistics anthropometric parameters were calculated for each dimension were calculated, according to the methodology known in the mathematical statistics⁶. The main parameters calculated were trend parameters (Average, Median, Mode, Central value of the string) and scattering parameters (Standard deviation, selection dispersion, Amplitude, Variation coefficient, asymmetry coefficient). Also, we checked the normality of frequency distribution by applying the criterion χ^2 , asymmetry, vaulting and excess coefficients)

Statistical analysis of primary survey data led to the development of two national size systems standards used in the design and manufacturing of clothing by garment industry.

Standardized values were determined for the main statistical parameters of the main dimensions, body height (I_c), bust perimeter (C_g), waist perimeter (W_g), hip perimeter (H_g), height classes, the central values of the perimeter and an overall image on the studied anthropometric sizes was obtained.

The standardized values of the main dimensions represent central values of the classes constituted based on the known arithmetic mean of the selection and on the inter-dimensional interval settled for each size.

Between the principal and the secondary dimensions measured on the body, there are some complex connections of different types, expressed by non-linear relations, yet, that can take a linear form, thus obtaining a simple linear regression equation of the form:

$$Y_1 = b_0 + b_1x_i \quad (1)$$

or the multiple one:

$$Y_i = b_0 + b_1x_1 + b_2x_2 + \dots + b_nx_n \quad (2)$$

where:

- x_i – value of the independent variable – main/principal dimension;
- Y_i – computed value of the dependent (effect) variable, which estimates correctly the measured value of the secondary dimension Y ;
- $b_0 \dots b_n$ – coefficients of the regression equation.

The secondary body dimensions have been computed according to the mathematical model taking the form:

$$y = b_0 + b_1 I_c + b_2 B_g(C_g) + b_3 W_g \text{ sau } y = b_0 + b_1 I_c + b_2 B_g(C_g) + b_3 H_g \quad (3)$$

where:

- I_c = body height average value (cm),
- $B_g(C_g)$ = bust/chest circumference average value (cm),
- W_g = waist perimeter average value (cm),
- H_g = hips perimeter average value (cm),
- b_0, b_1, b_2, b_3 = coefficients of the regression line equation

The two standards are: SR 13544- Clothing. Men's Body Measurement and Garment Sizes and SR 13545- Clothing. Women's Body Measurement and Garment Sizes. So, SR 13544 presents the standardized body height and standardized variants of the Chest girth, respectively Waist girth, for the men body types (Table 1 and 3) and SR 13545 presents standardized body height and Standardized variants of the Chest girth, respectively Waist girth, for the men body types (Table 2 and 4).

Body height (cm)	158		164		170		176		182		188	
	min	max	min	max	min	max	min	max	min	max	min	max
Range	155	160,9	161	166,9	167	172,9	173	178,9	179	184,9	185	190,9
Intervals	6		6		6		6		6		6	

Table 1: Standardized body height for men

Body height (cm)	152		160		168		176	
	min	max	min	max	min	max	min	max
Range	148	155,9	156	163,9	164	171,9	172	180,0
Intervals	8		8		8		8	

Table 2: Standardized body height for women

Body type	$W_g - C_g$	Clothing sizes											
		42	44	46	48	50	52	54	56	58	60	64	66
		Body Chest girth (C_g)											
		84	88	92	96	100	104	108	112	116	120	126	132
Body Waist girth (W_g)													
A	- 20	64	68	72	76	80	84	88	92	96	100	106	112
B	- 16	68	72	76	80	84	88	92	96	100	104	110	116
<i>C</i>	<i>- 12</i>	<i>72</i>	<i>76</i>	<i>80</i>	<i>84</i>	<i>88</i>	<i>92</i>	<i>96</i>	<i>100</i>	<i>104</i>	<i>108</i>	<i>114</i>	<i>120</i>
D	- 8	76	80	84	88	92	96	100	104	108	112	118	124
E	- 4	80	84	88	92	96	100	104	108	112	116	122	128
Inter-dimensional interval		4 cm										6 cm	

Table 3: Standardized body type and Clothing size for men

Body type	$H_g - B_g$	Clothing size											
		40	42	44	46	48	50	52	54	56	58	60	
		Body Bust girth (B_g)											
		80	84	88	92	96	100	104	110	116	122	128	
Body Hip girth (H_g)													
A	-4	-	-	-	-	-	-	100	106	112	118	124	
B	0	80	84	88	92	96	100	104	110	116	122	128	
<i>C</i>	<i>4</i>	<i>84</i>	<i>88</i>	<i>92</i>	<i>96</i>	<i>100</i>	<i>104</i>	<i>108</i>	<i>114</i>	<i>120</i>	<i>126</i>	<i>132</i>	
<i>D</i>	<i>8</i>	<i>88</i>	<i>92</i>	<i>96</i>	<i>100</i>	<i>104</i>	<i>108</i>	<i>112</i>	<i>118</i>	<i>124</i>	<i>130</i>	<i>136</i>	
E	12	92	96	100	104	108	112	116	122	128	134	140	
F	16	96	100	104	108	112	116	-	-	-	-	-	
Inter-dimensional interval		4 cm						6 cm					

Table 4: Standardized body type and Clothing size for women

The standardized values of the male body height, within the $\Delta I_c = 6$ cm inter-dimensional interval, are: 158 cm, 164 cm, 170 cm, 176 cm, 182 cm and 188 cm. The standardized values of the female body height, within the $\Delta I_c = 8$ cm inter-dimensional interval, are 152 cm, 160 cm, 168 cm and 176 cm. Relative frequency of standardized heights in the total selection is in Figure 1a and Figure 1b.

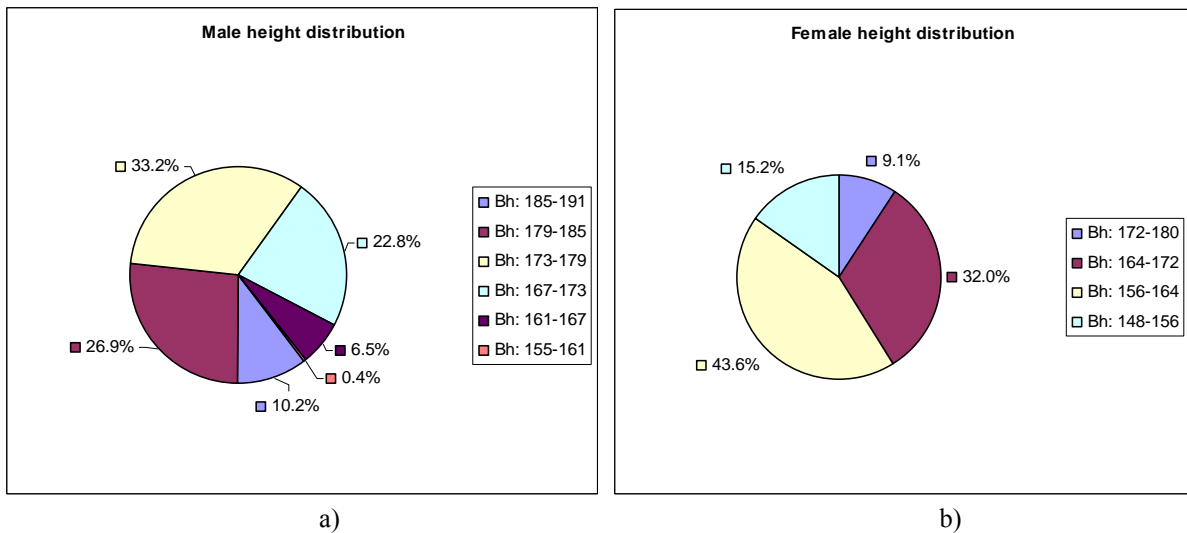


Figure 1: Relative frequency of standardized heights in the total selection, a- male and b-female

Analyzing the graphics, we notice that the highest representativeness (43.3%) in the studied selection belongs to the female population in the 148-156 cm height interval, followed by the 156-164 cm height interval (32.0%), while for men the highest representativeness (33.2%) is taken by male in the 173-179 cm height interval, followed by the 179-185 cm height interval (26.9%) and the 167-173 cm height interval (22.8%).

Representation of relative frequency, on body types in the total selection, for the men and women is shown in the Figure 2a and 2b.

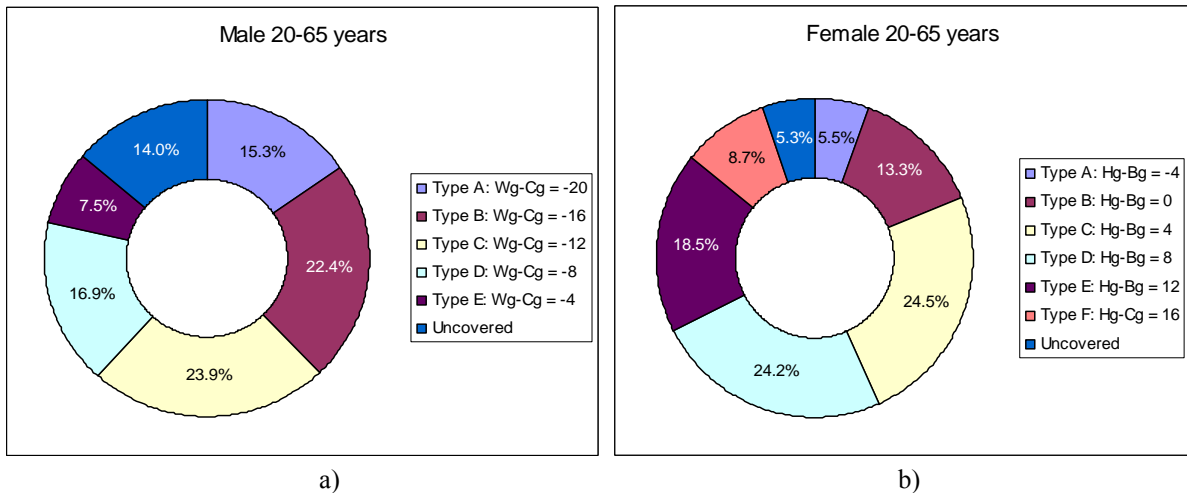


Figure 2: Distribution of standardized body height in the total selection, a- male and b-female

The relative frequency of body type in male and female age groups is shown in Figure 3 and Figure 4.

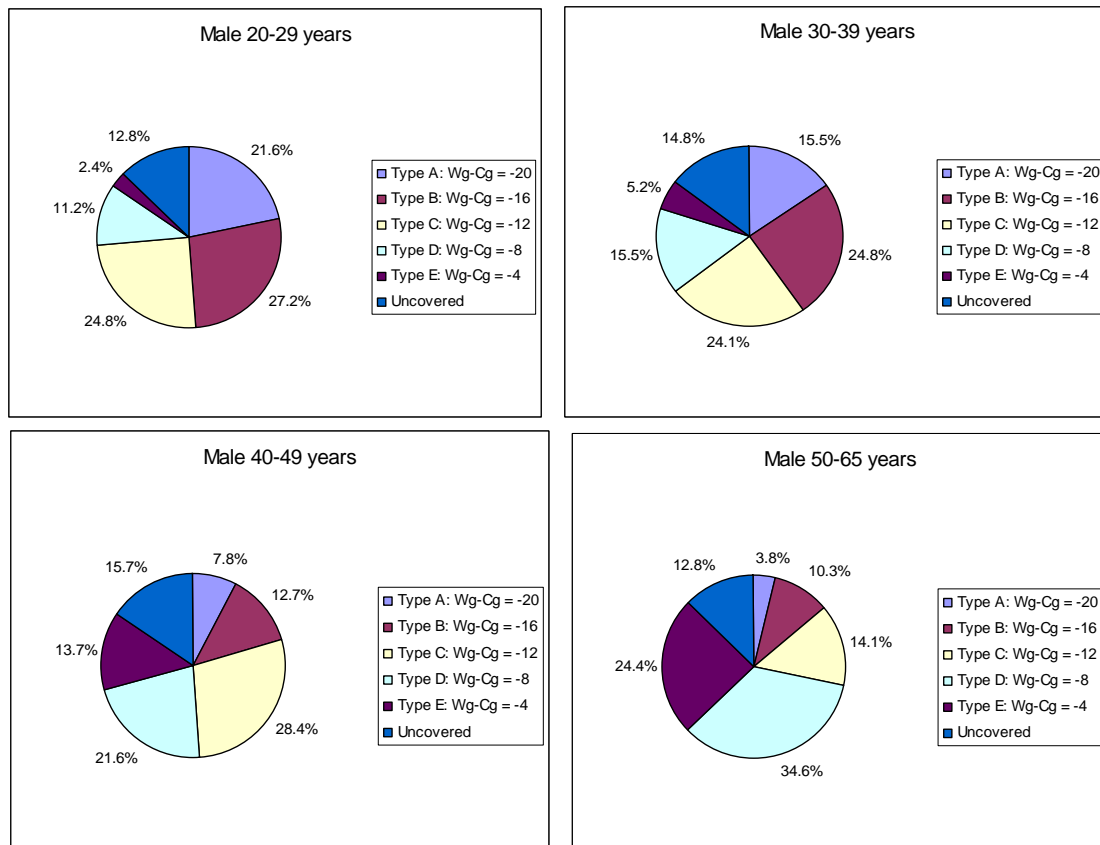


Figure 3: Distribution of standardized body type in the men ages group

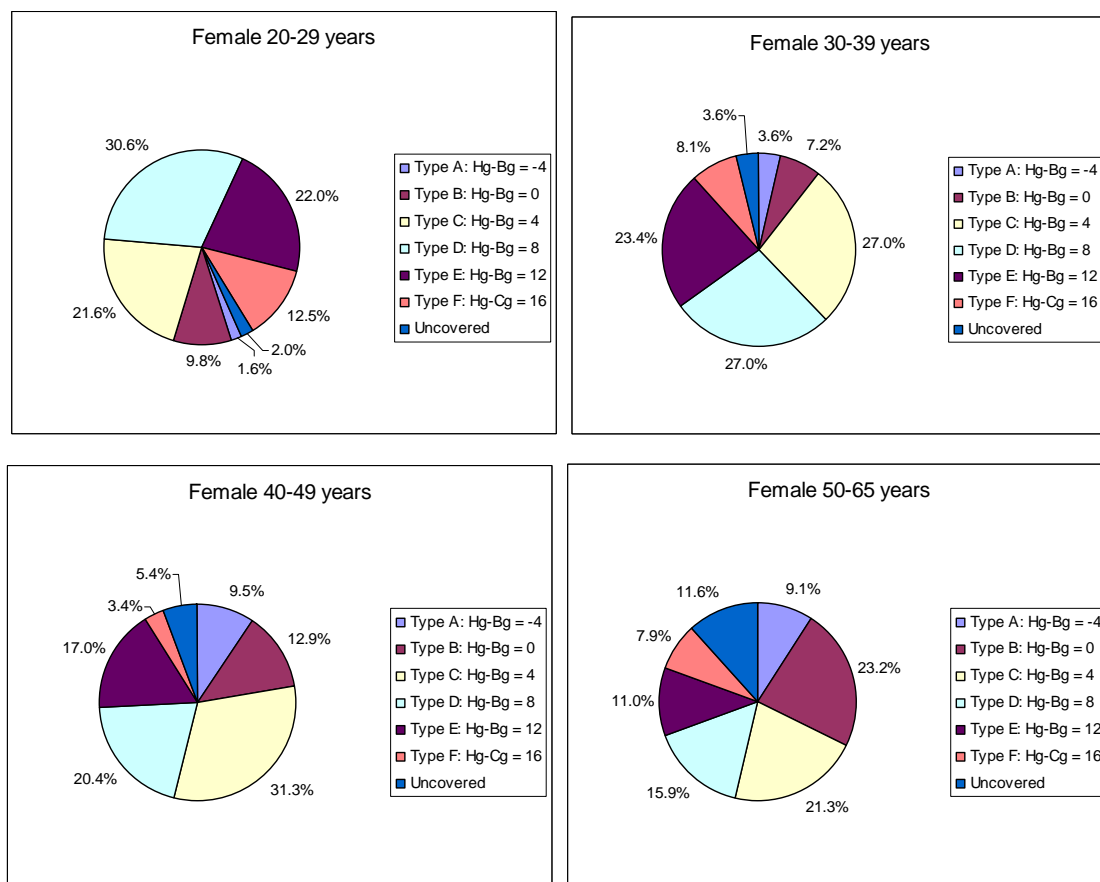


Figure 4: Distribution of standardized body type in the women ages group

We should note that the representative body type for men aged 20-29 years group is B (27.2 %). This changes with age and the most common body type for the 50-65 years group is D (34.6%). For the women aged 20-29 years group the representative body height is D (30.6%) while for the 50-65 years group, the representative body heights are B (23.2%) and C (21.3%).

4. CONCLUSION

Exploiting the possibilities offered by the 3D Scanning System is essential for the garments industry, as well as for other areas where anthropometric data are absolutely necessary and irreplaceable.

Updated anthropometric standards are a priority for the garment industry at both the national and European level in view of the compatibility of anthropometric data needed for the European unified system designation. In the future, 3D scanning technology will make possible the operation and management of customer needs and preferences, the development of sophisticated CAD systems, the solutions for achieving virtual prototyping and flexible manufacturing systems and customer oriented logistics.

Internet based communication systems for manufacturers, distributors and users will allow textile and garment manufacturers to successfully develop customized manufacturing systems comparable with mass manufacturing systems.

As a general conclusion, knowledge of statistics on the anthropological aspect of Romania's population, have an importance in the academic research, applied and fundamental. Thus anthropometric data obtained from anthropometric surveys can be used to develop new projects and applications as:

- Health management system. Anthropometric measurements allow determining the health status of population trends and developments resulting from these measurements of variables. It can calculate: health index, body mass index and waist-hip ratio, important indices in establishing of metabolic disorder; Analyzing the Body Weight Index, for the selection, we be notice the results in table 5.

Assessment of health status/Body weight index	Age range of male (years) / BWI (%)					Age range of female (years)/BWI (%)				
	20 -65	20- 29	30 -39	40 -49	50 -65	20 -65	20 -29	30 -39	40 -49	50-65
Underweight / <18.5	1	3	0	1	0	7	15	4	3	0
Normal weight / 18,51-24.99	32	48	27	20	15	52	78	54	40	15
Overweight / 25-29.99	45	35	47	52	54	24	6	26	35	54
Grade 1 obesity / 30 - 34.99	18	13	21	19	26	12	1	13	16	26
Grade 2 obesity / 35 -39.99	3	1	4	5	5	4	0	3	5	5
Morbid obesity / > 40	1	0	1	3	0	1	0	0	1	0

Table 5: Distribution of body mass index by gender and age

- Optimization of fields in which the size of the human body are the basis for product development or planning of housing or employment;

- Ergonomics, to extract information about spatial position of the joints, which are relevant to specific sequences of moves; Ergonomic design for sports equipment; Design of auxiliary devices for the disabled people.

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THE MOHAIR – PRECIOUS SOURCE OF RAW MATERIAL IN ROMANIA

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Keywords: Romanian mohair, acclimatization, characteristics, fibers

Abstract: *“Returning to Nature” is a growing tendency in the textile industry. Chemical fibers had known spectacular, even fascinating developments over time, trying to imitate nature in all its specific aspects. Despite this expansion of the production and processing of chemical fibers with extremely diversified and sophisticated characteristics, the specific properties of natural fibers and especially those of animal hairs could not be equalized. The use of these precious raw materials, the so-called noble fibers or “luxury hair fibers” overcame the barriers of “luxury” products, becoming a characteristic of the textile product market in the last years. In Romania, Angora goats were brought as donations, in order to reinvigorate Romanian livestock farms. The National Research and Development Institute for Textiles and Leather Bucharest initiated in collaboration with the FERM PROD Ltd. company from Braila county (area favorable in terms of environmental conditions and climate) an acclimatization project in Romania of a nucleus of Angora goats.*

The paper presents aspects regarding:

- *the acclimatization process of animals, their breeding and multiplication;*
- *the comparative study of the main characteristics of Romanian Angora mohair type of fibers: physical-mechanical, chemical, electronic microscopy, thermo gravimetric properties;*
- *aspects regarding the processing of mohair /wool fibers blends and/or wool type chemical fibers, for obtaining woven fabrics with superior aesthetical and comfort characteristics.*

1. INTRODUCTION

The tendencies of fashion towards clothes having special comfort characteristics have determined, in the last period, the manufacturers to focus their attention towards a greater usage of natural animal fibres. Usually known under the generic title of noble animal fibres, these fibres have specific characteristics: they are soft, fluffy, handle, bulky and have superior thermal isolation, breathability, air and humidity permeability that give to the products containing such fibres an increased degree of comfort in wearing, the possibility of adjusting to different environmental temperatures, maintaining the thermal equilibrium of the body.

The market researches indicate that the society’s evolution has determined, and still does, a certain change of the consumers’ perspective. Their requests and exigencies go beyond the level of quality textile products, reaching a superior one: natural fiber products, with a high added value, that bring “services” to the consumer, such as: comfort, easy care, functionality,

“anti” properties: anti-soiling, anti-felting, anti-moths, odour control.

Globally, the major concerns of the consumer goods textiles’ manufacturers meet these requests and refer to:

- the use to the full extent of natural textile fibers;
- the increase of the products’ added value;
- the production of quality products that combine the engineering factors with the aesthetic and economic ones.
- The production of quality products that combine the engineering factors with the aesthetic and economic ones.

The paper presents aspects regarding the acclimatization process of the goats, a study of the complex structural properties of Romanian Angora mohair, as compared to those corresponding to wool fibres, through:

- electronic microscopy
- thermo gravimetric analysis;
- birefringence analysis.

The physical-mechanical and physical-chemical properties of raw and washed mohair fibers and their evolution during the acclimatization of goats (period 2003-2010) are also investigated.

Further on, aspects regarding the processability of the Romanian mohair fibres for obtaining yarns and woven fabrics containing mohair, wool fibres and/or wool type chemical fibres, with superior aesthetic and comfort characteristics and high added value are presented.

2. ASPECTS REGARDING THE ACCLIMATIZATION PROCESS OF THE ANGORA GOATS

Starting the acclimatization process, some conclusions can be drawn:

- animals have adapted easily to the new living conditions; after five years of breeding the Angora goats at FERM-PROD, one can say that the acclimatization process is completed: quantity of mohair: 4-6 kg fiber per animal; most animals are now the 4th-5th-6th generation; goats that produce two kids are in percentage of 50-60%;
- nevertheless, because of the inbreeding process, the following aspects were noticed: the percentage of healthy kids at calving, the body weight and the quantity of fiber per animal and animal size were reduced.

In this situation, the specialists from FERM-PROD made tests for cross-breeding; 20 females were crossbred with males of common breed. The following aspects were noticed:

- some kids kept the mother genetic character and the fleece aspect is specific to Angora
- other kids have mainly their father character and the Angora specific aspect has been lost



Figure 1 Inbred kid with small size and low amount of fibres [1]

At present, actions for purchasing 5 Angora males from Turkey in order to restore the specific characteristics of the breed are being carried out.

3. CONTRIBUTIONS TO THE STUDY OF THE PHYSICAL-MECHANICAL CHARACTERISTICS OF THE ROMANIAN MOHAIR FIBRES

The main physical-mechanical characteristics for Romanian mohair fibers (2003) and 2010, as compared with Romanian wool fibers are presented in table 1 and table 2.

Mohair fibres		Young Angora goat	Romanian wool sort29P
Characteristics			
Diameter	µm	30,3±2,1	29.6±2,5
	CV%	26,9	31,9
Individual length	mm	102±3,5	100,7±3.0
	CV%	56,6	50,0
Breaking Force	cN	32,67±9,3	24,53±10,1
	CV%	46,8	51,1
Elongation at break	%	50,58±2,3	37,58±4,6
	CV%	11,7	23,1
Number of crimps/cm		0,7	5,3
Friction coefficient fiber/fiber	static	0,217	0,424
	dynamic	0,192	0,390
Friction coefficient fiber/metal	static	0,260	0,318
	dynamic	0,224	0,295

Table 1 Physical-mechanical characteristics (2003 fibres)

Mohair fibres		Kids goat Age 6 months	Young goat Age 1 year	Romanian wool sort 29P
Characteristics				
Diameter	µm	23,4	30,2	30,1
	CV%	34,3	23,9	31,9
Comfort factor				
	%	84,6	51,1	50,2
Individual length	mm	148,66	152,24	100,7
	CV%	46,83	34,58	50,0
Breaking force	cN	19,6	18,81	10,8
	CV%	45,63	19,21	51,1

Elongation at break	%	38,6	41,11	39,1
	CV%	14,81	10,0	23,1
Number of crimps/cm		0,700	0,714	5,3
Friction coefficient fiber/fiber				
	static	0,320	0,334	0,424
	dynamic	0,281	0,310	0,390
Friction coefficient fiber/metal				
	static	0,371	0,327	0,318
	dynamic	0,353	0,300	0,295

Table 2 Physical-mechanical characteristics (2010 fibres)

The following aspects can be highlighted:

- Mean diameter is found around 30 μm , for the fibers coming from adult goats, a value comparable with the one corresponding to the semi-fine wools, sort 29P (21); no modifications are noticed as far as samples in the 2010 production are concerned, as compared to the 2003 production;
- Mean length of the mohair fibers in the 2010 production shows a higher value (140mm), in comparison with fibers produced in 2003 (100.2mm);
- Staple fibers content has high values in case of mohair as compared to wool, as this is generally a characteristic specific to goats (Angora, Cashmere) and camellids (camels, alpaca), being formed out of the fibers layer on the animal skin (ca. 14% of total fleece);
- A reduction of the breaking resistance is determined for the 2010 production fibers, as compared to the 2003 production fibers, a phenomenon that can be seen as an effect of the acclimatization process and animal consanguinity;
- Friction coefficient values prove a slight increase in case of 2010 production fibers, as compared to 2003 production fibers, a process that can be explained by possible changes of the scales, which, due to acclimatization, thickened and became more prominent;
- Number of wrinkles for the mohair fibers is 0.7 wrinkles/cm, with 86% lower as compared to the one corresponding to wool fibers (5.3 wrinkles/cm); these aspects are due to differences existing between the two types of fibers at the level of cuticle cells and are worth being considered when designing the fibrous blends and, further, when managing the technological processing stages;
- Luster is influenced by the cuticle cells characteristics, which determine an increase of the even reflecting component to the decrease of the diffuse reflecting one, thus leading to a more intense luster, as compared to wool;
- Whiteness degree determined by the Elrepho method amounts to 37.90 for the mohair, which shows a white color with a soft yellowish tint favouring the fiber luster.

It can also be observed that the variation coefficient of all characteristics is high; this is a specific characteristic of animal hairs. Also, it can be seen that the number of crimps is low, as compared with wool fibers; the friction coefficients, fiber/fiber and fiber/metal have also low values.

This aspect determines the lowest adherence of the mohair fibers.

4. CONTRIBUTIONS TO THE STUDY OF THE STRUCTURAL PROPERTIES OF THE ROMANIAN MOHAIR FIBRES

The mohair (keratin fibre) is characterized morphologically by the existence of three distinctive cellular layers: cortical layer, cuticle layer and medulla. Medulla is specific for coarse fibres, with diameter over 35-38 μm . For showing the longitudinal aspect of the fibres, electronic microscopy analyses (STEREOSCAN 250) are performed in the laboratories of our institute: fibres –production 2003 and fibres –production 2010.

Figure 2 shows the fibre longitudinal surface for mohair fibres-2003, as compared with wool fibres.

Figures 3(a) and (b) show the fibre longitudinal surface for raw and washed mohair fibres-2010, (SEM QUANTA 200, GSED).

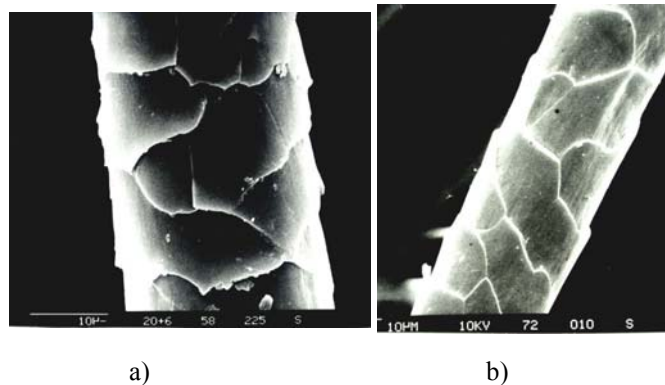


Figure 2 The aspect of the longitudinal surface for the wool fibres (a) and the 2003 mohair fibres (b) [2]

The existence of some fine denticulate cuticle cells, with sharp peaks and smaller thickness (scale height) in comparison with wool fibre scales is observed.

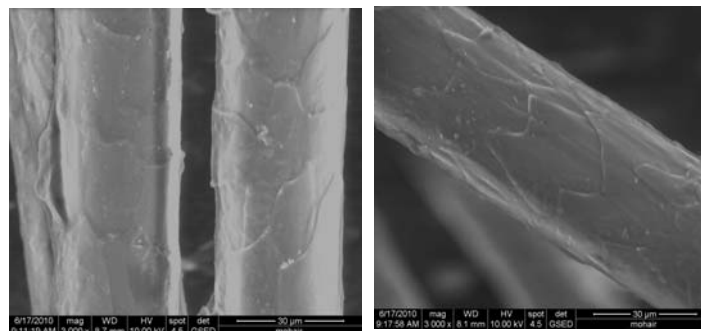


Figure 3a The aspect of the longitudinal surface for 2010 raw mohair fibres [2]

The impurities, sebum and fat adherence of the fibres are also present.

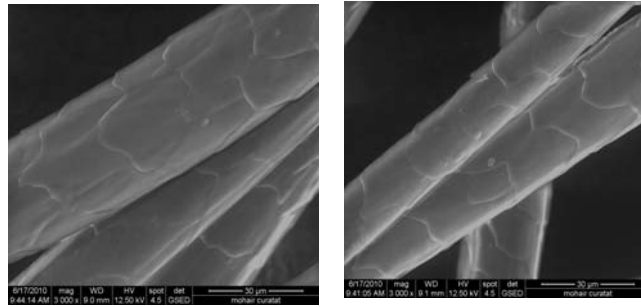


Figure 3b The aspect of the longitudinal surface for 2010 washed mohair fibres [2]

The longitudinal surface aspect of the mohair fibres is more uniform as compared with wool fibres.

There are not significant differences between the analyzed fibres (2010 as compared with 2003).

The specific surface scale appearance is one of the factors that determine the high natural luster degree and the improved tinctorial properties of mohair fibers.

Keratin fibres are generally characterized by the existence of two types of cortical cells, ortho and para cells, present in different ratios within the morphological structure of the cortex. The ortho-para quantitative ratio and the distribution of these cells in the fibre cortex are characteristics that modify substantially their properties.

The analyses of electronic microscopy undertaken in the institute specialized laboratories have presented a cortical structure formed of orthocells and para heterotype cells (cells of transition from ortho to para) in mohair fibres.

The researches made have emphasized a close connection between the cortical structure and the fibre crimp. Mohair fibres have a reduced number of crimps (0,7/cm) and a monotype distribution (ortho-cortical cell and of transition ortho → para).

Figure 4 shows the aspect of the cross-section for the mohair fibres. For obtaining the cortical structure a coloration specific to the paracortical cells (silver nitrate 2,5 %) has been effected in the testing laboratories of the institute.

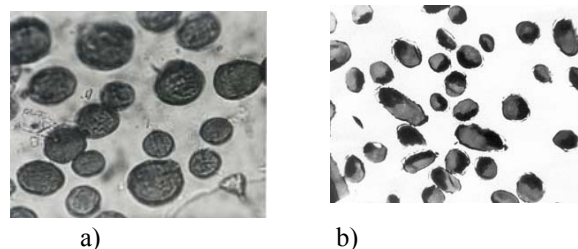


Figure 4 Aspect of the cross-section for mohair fibers (a) and wool fibers (b) [2]

The section does not show clear differences of colour inside the cortex as it is in the case of fine wools, a fact that proves the character of ortho- paracortical transition of the cells.

The structural differences showed by electronical microscopy represent the final effect of the biophysical and biochemical process that conditioned the route from the liquid stage of cytoplasm of the living cells to the reinforced stage of the keratinized material. The keratinization process, which is a process of intercellular dehydration, occurs slowly in keratin fibres (merinos fine wools). Intermolecular friction forces inside the cells determine the orientation of the polypeptidical wools, generating the appearance of a bilateral structure strongly oriented (para cells and orthocortical cells). [3]

Unlike this case, the process of orthokeratinization, specific to the mohair formation, is

preceded by a swelling of the cellular cytoplasm, influenced by a higher water content of the cells. Due to high pressure, the dehydration occurs fast, causing the appearance of a fibrillar structure less ordered. This structure has a smaller density. Thus, orthokeratin occurs.

The lack of the para cells, strongly reticulated, generates an unsteady character and an increased reactivity of fibres towards chemical agents.

The thick mohair fibers with a diameter exceeding 38-40 μm are characterized by the presence of the medullar channel, situated at the center of the cross-section;

The presence of the medullar channel roots back in the insufficient keratinization of the fiber and represents, at the same time, a result of the lower inclusion of sulphur-containing amino-acids (cystine).

5. THERMOGRAVIMETRICAL ANALYSES

a) 2003 mohair fibres

Work method:

To ensure the possibilities of comparing the results of the mohair and wool fibres samples, the figures were recorded by MOM 1500 D Budapest, which has a system of collecting computer data. The initial temperature was $T_0=26^\circ\text{C}$.

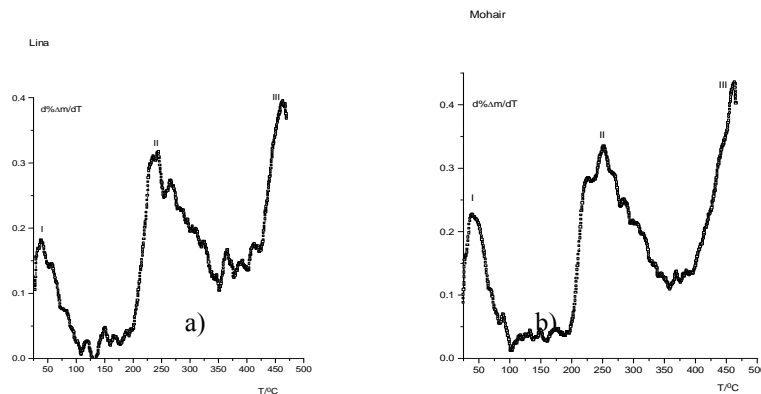


Figure 5: DTG curves for wool (a) and mohair fibers (b) [3]

Temperature $^\circ\text{C}$	Mass loss, % Δm		Ratio % Δm mohair/wool %
	Mohair	Wool	
125	10,7	8,7	123
192,5	13,2	10,5	125,7
363,5	48,8	42	116,1
466	72,2	66,5	109

Table 3 The variation of procentual mass loss, depending on temperature, for 2003 mohair fibres and wool fibres [3]

The analyses of the figure 5 and the data presented in the Table 3 show the following aspects:

- Temperature rising up to 125° determines a process of water elimination by evaporation,

corresponding to a mass loss of 10,7 % for mohair fibres by about 23%, higher than the adequate value of the wool fibres, which is 8,7%. During this interval, the average temperature of heat absorption adequate to the maximum speed of humidity elimination (first endothermic peak) has values ranging between 50 and 80⁰ C. The higher value of mohair fibres mass loss due to humidity elimination can be in relation with the higher water content of these fibres and with the structural differences specific to the process of orthokeratinisation. This process is presented by electronic microscopy analyses and X-rays diffraction.

- after the humidity elimination, the thermal degradation of the fibres occurs in two stages: decomposition and thermo –oxidation.

- as temperature increases, the procentual mass decreases both for mohair and wool; thus, the fibre decomposition occurs. When temperature is about 200-228⁰C, at a value of mass loss of 13,2 – 15%, a supercontraction of fibres associated with a shortening of the molecular chain occurs.

The second endothermic peak occurs at the temperature of 260-275⁰C at the level of heterotype para-cortical cells, with a higher cystine content.

- starting with this temperature, the fibres samples decompose quickly. During the decomposition process, the mohair loses 9-25% mass more than wool does, with close values of temperature. Thus, at temperature of 360⁰C the mass loss has the value of 48,8% for mohair and 42% for wool.

- the second stage of the fibre degradation starts with a temperature of 400⁰C, when the fibre thermo –oxidation occurs and the value of mass loss is 72,2% for mohair and 66,5% for wool.

- at 500⁰C, the thermal decomposition is complete.

b) 2010 mohair fibres

Work method:

- STA 6000-PerkinElmer- SUA - Simultaneous thermal analyzer
- Mass: 4,1 mg
- Temperature range: 25-700 °C
- Air (20 ml/min)

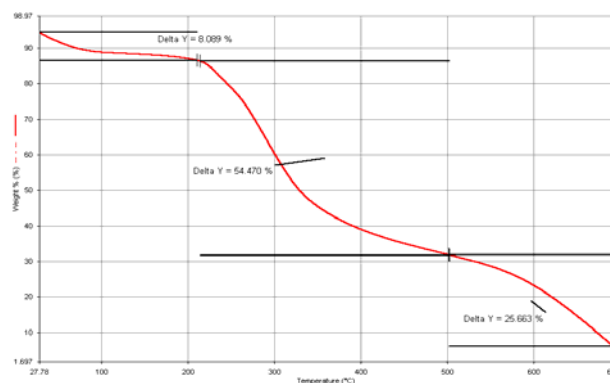


Figure 6. The variation of mass loss depending on temperature, for 2010 mohair fibres [3]

Temperature ⁰ C	Mass loss, % Δm
27 – 225	8,089
225 – 500	54,47
500 – 692	25,67
> 700	11,78

Table 4. The variation of procentual mass loss, depending on temperature, for 2010 mohair fibres [3]

The highest mass loss (thermo degradation of the fibres) occurs at a temperature of 225-500 ⁰C. The analyses of the figure 6 and the data presented in the Table 4 show that there are not differences between the temperature behavior of the 2003 as compared to 2010 mohair fibres. The different behaviour of wool and mohair fibers under the temperature action is caused by the ortho-keratinization process specific to mohair that generates a more unsteady or instable structure, which is bulkier and richer in the water content.

6. CONCLUSIONS

Globally, the use of “rare” animal fibers, also known as “noble, precious, special fibers” has increased considerably in the recent years.

Taking into account the global trends in the field, the acclimatization of a nucleus of Angora goats in Romania, the setting up of a new autochthonous base of valuable raw materials and the evaluation of the possibilities of efficient processing of these fibers represent an alternative for the Romanian zootechnical sector and a challenge for the scientific research and textile industry of our country.

The issues presented show the importance given to mohair fiber production and processing in Romania and motivate the continuation and extension of the researches for finding opportunities to exploit this valuable raw material.

Research will continue for developing the range of products containing mohair fibers and mohair can become a valuable source of raw material for the Romanian textile industry.

ACKNOWLEDGEMENT

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FP7 project: “Virtual Collaborative Design Environment”

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Keywords: textiles, virtual design, collaborative platform

Abstract: *The objective of the FP7 project “Virtual Collaborative Design Environment”, acronym: **EnviroTex-Design** is to develop an interactive **web-services platform** to stimulate collaboration between Clothing & Leather/Footwear SMEs to design and manufacture safety products with the desired performance characteristics. The **Collaborative Virtual Design Platform** provides to designers, retailers and manufacturers, a quick and collaborative guidance on the textile and leather design process from the very beginning till the development of the end product with the desired performance characteristics and special concern to environmental, health and toxicological regulations and standards. The platform assists users in formulating queries to meet their information needs, to find the most suitable partners to react quickly to the new market opportunities, to enhance effective knowledge sharing between SMEs.*

1. INTRODUCTION

Virtual Collaborative Design Environment project is a FP7 addressing the topic NMP-2007-3.3-1 Innovative Customer-Driven Product-Service Design in a Global Environment. Starting from 2008, with 36 months duration, the project included 16 partners: 4 Research Partners (FHF, INCDTP, Elkede and IFTH), 4 Technology partners (ATC, Inotex, MTS and TTX), 2 Professional Associations (APM and UIT), 2 large companies (Color-Web and Slezan) and 4 SMEs (Flory, Mari, Pecci and Vasiliadis).

The main goal of the project is to create a web-based platform for the design, development and delivery of the garments and leather products. The platform provides to designers, retailers and manufacturers, a quick and collaborative guidance on the textile and leather design process from the very beginning till the development of the end product with the desired performance characteristics and special concern to environmental, health and toxicological regulations and standards.

2. The structure and components of the “Collaborative 3D Virtual Design Platform”

The Collaborative Platform is a highly optimised and fast network communication for real-time data exchange, enabling designers and producers to define production process and avoid long and expensive testing and sample making.

An easy to use structure was conceived to help partners to:

- collect information about materials properties and performances;
- **select** functionalities, sub-functionalities and properties of the components (fabric, yarns, fibres, accessories) used to manufacture a final product like garments and shoes;
- **get information** about the regulations that apply world-wide regarding the **restricted**

chemical substances and the limits permitted in the final product and avoid the environmental impact of their products and processes; communicate on products' compliance with performance and EHS requests/certifications (anti-allergic, anti-bacterial, eco label), REACH demands;

- **create new products** or to **assess the performance** of the final products during the design phase **without the need to manufacture and test physical prototypes**;
- **simulate** the final product without the necessity to create a physical prototype, develop “Rapid Prototyping” enabling the transformation of the virtual prototype into a physical one
- **generate** technical Data Sheets and produce sheets of the designed final product;
- **select the cost-efficient technologies**;
- **identify and set-up** the supply chain tailored on the new product characteristics; select one or several potential partners to involve them in the product chain.

The “Collaborative 3D Virtual Design Platform” proposed by EnviroTex-Design project has the following structure:

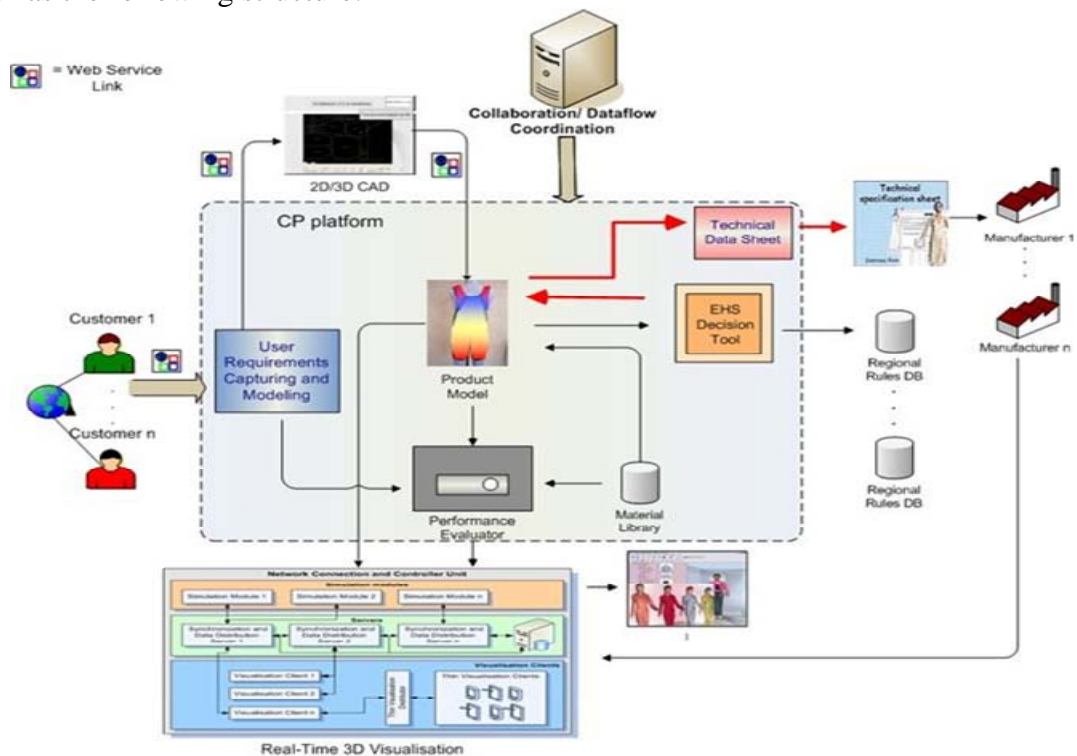


Figure 1. Virtual Collaborative Platform

The main components of the “3D Virtual Design Collaborative Platform” are the followings:

- an intuitive **user interface** enabling real time interaction between customers and producers
- a **performance evaluation module** enabling producers and/or designers to **assess the performance** of their final products during the design phase **without the need to manufacture and test physical prototypes**
- an extensive, interactive, collaborative digital **material library** (with access security) which allow designers to choose the textile products (fabric, yarns, fibres, accessories) with required end-use properties
- an **EHS decision making toolbox** to determine the toxicological & environmental impacts in the design stage

- a **dynamic real time simulation** and **visualisation** module enabling the transformation of the virtual prototype into a physical one and speeding up the product design and manufacture. Created by Fraunhofer institute ((FHF-IGD, Germany), the module allows arrangement of the garment around an avatar by loading pattern shapes, textures, seams and accessories
- a **technical datasheet generator** enabling designers to define production process and automate generation of the technical data sheets
- a regional network of enterprises (**Extended Micro-Factory**) enabling a fast identification and dynamic setting-up of a supply chain tailored on the new product characteristics.

3. The innovation brought by project

The most important innovations brought by each module developed during the project are shortly described below.

The **Performance Evaluation Module (PEM)** is the first Software enabling producers and/or designers **to assess the performance** of their final products during the design phase **without the need to manufacture and test physical prototypes**.

PEM is a decision tool offering the possibilities to: evaluate/compare/select the global performance of a product before manufacturing, benchmark existing products or designing new products. The evaluation is objective being based on mathematical modelling of the normalized parameters considered relevant to quantify the response of the product.

PEM can calculate the performance of any object and its components no matter the unit measurement and value range of the parameters, the level of involvement, the domain of interest, etc. (e.g. physical properties, costs, sensitive perceptions, subjective aspects, environmental impacts, safety considerations). The only requirement is that each parameter has an objective numerical value measured (determined) on a standardized scale.

PEM **can extrapolate missing values using Behavioural Modelling Tool** (sub-module of PEM) and the Integration Matrix (sub-module of BMT) based on statistical equations.

The global performance of the product can be displayed as scale, spider diagram or bar diagram.

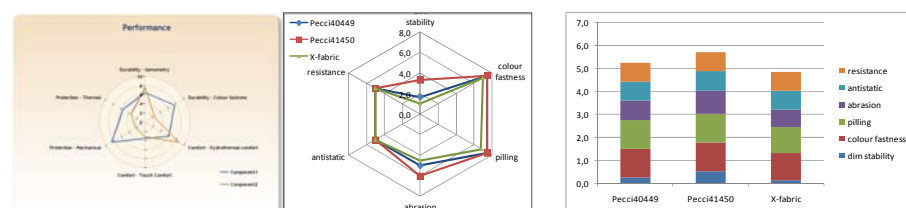


Figure 2 Global performance representation

PEM can be used, as separate software or integrated in the collaborative platform, as decision support in textile industry and for studies in research institutes.

Integrated in the platform, PEM is linked to Material Library, Collaborative dynamic real-time simulation module and EHS module.

The Material Library (MatLib) is an extensive, interactive, collaborative database for a large range of textile products characterized by an exhaustive number of parameters. This unique database containing components composing a whole product from the raw material to the fabric including yarns and any accessories like buttons, zipper, films etc. is used by PEM to calculate the performance.

A finishing process list allowing EHS tool calculating EHS impacts is also contained in the

MatLib.

MatLib is linked to datasheet generator to deliver technical specification, to PEM which initiates automatical query within MatLib to evaluate performance of components, and is linked to EHS toolbox providing EHS information.

Environment/Health/Safety (EHS) module is a database collection of approximately 800 most used substances in the textile and leather industry, selected according to their possible impact on the environment and health consumer. Restricted substance lists were allocated under mandatory global legal regulations, but also voluntary brand (Retail and fashion companies) and private labels (like Oekotex standard 100) restrictions and considering public perception and NGO expectations.

The main innovation of the visualisation module is the ability to visualise the distribution of toxic substances, or alternatively, the performance characteristics as they are computed by the PEM, for each individual part of the product.

The Production Framework, integrated into the Collaboration Platform, includes all relevant tools (Demand Form, Bill of Materials, automatic Product Specification Overview containing the relevant data on the product, Extended Micro Factory database, Production Sheets linked to EHS) which provide users the ability to efficiently interact in the different stages of the design process, in full respect of internal confidentiality.

The Contractor could select potential partners registered with the Extended Micro Factory (EMF), based on online data regarding their capacities and on objective evaluation parameters stored in a private area.

Production Sheets provide designers with reliable data to initiate the full process ranging from the design to the 3D visualization including EHS assessment, the interrogation on available materials on MatLib and Performance simulation and evaluation.

Data Sheet Generator provides a useful and complete technical specification of the product including performance parameters and the restricted substances existing on material.

4. Conclusions

The Collaborative 3D Virtual Platform is a helpful tool:

- Developing reactivity : (Time to Market Reduction) Virtual Prototyping
- Fostering Creativity: (Better Consumer Knowledge) Permanent Collection
- Promoting flexibility : Co-operative Organisation
- Compliance with European Chemical Law (REACH)
- Better knowledge of material performances
- New production organisation enabling short runs and fast reaction to the new trends
- Improved product quality

Customer Needs

- Comfort and design : enhanced creativity
- Involvement in the design process : cooperative process
- Customised product : short runs
- Health and safety compatible with quality & performance
- Time to market according to trend evolution
- Costs

Ultimate objective:

- Reduction of design, prototyping and production time and costs
- Better interaction among customers and producers

- Anticipation of issues that are normally considered after the design phase.

To provide industrialists with:

- A collaborative 3D virtual environment enabling multidisciplinary teams cooperating in the product design to collect at early stage emerging demands and constraints
- Decision making tools and guidelines supporting toxicological and environmental constraints all along the design process
- A performance evaluation application enabling the selection of the best functionality according to the expected performance
- A production enabling an automatic generation of technical data sheets integrating performance parameters

Expected Benefits

Eco-Text-Design focuses on the mass - customisation model by tackling the most crucial needs that obstruct the globally competitive and sustainable future manufacturing sectors in Europe:

- Prototyping time reduction from an average of 7 weeks in clothing industry to less than 1 thanks to the extensive knowledge provided by the “collaborative design platform”;
- Faster development of new high-quality high-performance customer-oriented products;
- Reduction by 60% of the number of prototypes to be physically submitted in clothing thanks to more realistic virtual rendering of the product in terms of conformity and performances;
- 80% reduction of the number of product & manufacturing errors at design stage thanks to the collaborative simulation and visualisation capabilities at virtual design stage;
- Reduction of product development cost by 30% as a result of the real time collaboration;
- Dramatic reduction of the analytical testing;
- Decrease of the effort devoted to applying standards and regulations (national/international legislations) necessary to develop high quality “clean” products and processes thanks to the timely adoption by the SMEs of EHS standards;
- In the textile industry, reduction of the time to market from currently 2 months to less than one;
- Reduction by 90% of the risk of product recalls due to the non respect of the EHS constraints;
- Better adaptation to consumer & market behaviour thanks to the “Collaborative 3D virtual design platform”;
- Increased turnover by 20%;
- Reduction of unsold goods by 75%;
- Evolution of communication with customers from traditional methods to Web-based applications;
- Eco-Text-Design will consider the design process while analysing the environmental impact in terms of both product and process;
- This forecasting activity significantly reduces the life cycle cost.

Special acknowledgment to *dr.* JEAN MARIE BACHMANN (Institut Français Textile Habillement –IFTH, Troyes, France), *dr.* MARCO BARBIERI (Tecnotessile, Prato, Italy), *dr.* Eric Boudon (Institut Français Textile Habillement –IFTH, Paris, France) and to all partners of EnviroTex Design Project.

FUNCTIONAL DESIGN OF KNITTED FABRICS BASED ON THEIR THERMAL DOMAIN

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Keywords: Knitted fabric, Thermal field, Thermal resistance, Water vapour resistance

Abstract: *The aim of this paper is to establish the structural parameters and thermo-physiological comfort characteristics of knitted fabrics with single jersey structure, produced on a STOLL CMS 530 MULTIGAUGE knitting machine, gauge 6.2 E. As these fabrics are intended for clothing worn directly on the skin, the selected raw material includes: 100% cotton yarns, count Nm 50/2 and 50/50% cotton/PES blended yarns, count Nm 50/1. The knitted fabrics were subjected to dyeing operation using an AHIBA 1000 Turbomat installation type TM6B. The samples were tested for comfort characteristics—thermal resistance and water vapour resistance both in raw and finished state, in order to characterize and compare their thermal behaviour and point out the influence of the finished treatment.*

1. INTRODUCTION

Today the functionality problem of clothing products in terms of wearing comfort interests both the manufacturers of clothing worn daily and those with special destination. The important question which appears in this case is related to how the wearing comfort can be predicted from the selection phase of raw material and the design phase of textile materials. Now it is possible to provide thermo-physiological concrete information to all textile specialists, and with their help to create optimal clothing products with precise destination, without expensive wearing tests, for long time, which are not always conclusive because of the systematic test conditions absence and often reveals a weakness at the end of the test when it is already too late to intervene [1].

More than any other group of clothing products, the articles worn directly on the skin require thermo-physiological and sensory functions. Because of their properties, the knitted fabrics represent very important textile materials in performing the clothing products worn directly on the skin.

2. MATERIALS AND METHODS

The knitted fabrics were produced on a CMS 530 MULTIGAUGE 6.2 flat knitting machine, using two types of yarns—100% cotton yarns and 50/50% cotton/PES blended yarns [2].

After 24 hours of dry relaxation, the fabrics were measured to determine the raw structural parameters and the comfort thermal properties – thermal resistance and water vapour resistance. The knitted fabrics were subjected to dyeing operations with a direct

dye (Sirius Orange K-CFN) and a disperse dye (Dianix Luminous Red B) respectively [3, 4]. The samples were treated at 100°C temperature for 1 hour; the bath ratio was 1:30. Dyeing operations were performed on a dyeing machine AHIBA 1000 Turbomat type TM6B, according to the following temperature diagrams (Figure 1):

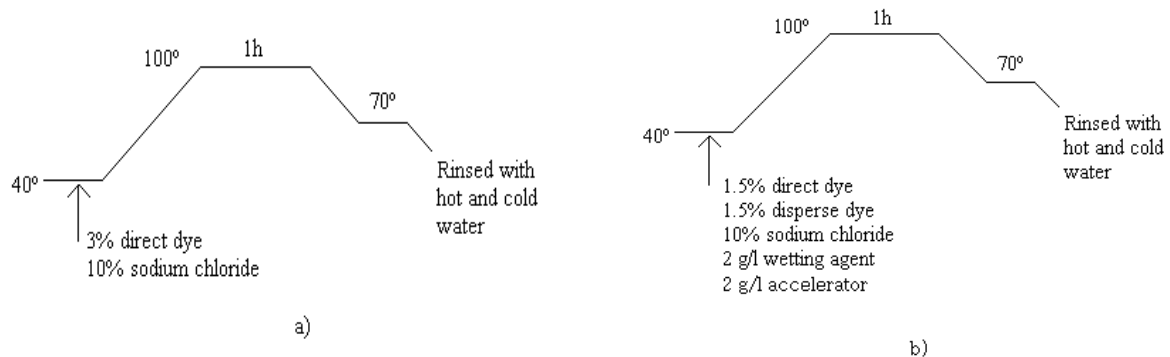


Figure 1. Dyeing diagram of knitted fabrics with a) direct dyestuff, b) direct and disperse dyestuff

After dyeing the samples were washed with hot and cold distilled water and then were dried without tension at room temperature. The dyed samples were again relaxed for 24 hours and tested for thermal resistance and water vapour resistance. The structural parameters were also determined.

The comfort characteristics were measured using the PERMTEST apparatus (Sensora, Czech Republic), similar to ISO 11092 [5], based on the Fast Skin Model.

3. RESULTS AND DISCUSSIONS

3.1 Structural parameters of knitted fabrics

The values of knitted fabric structural parameters are influenced by the characteristics of raw material, the knitted fabric structure and by finishing process.

For the raw and dyed knitted samples, the following structural parameters were measured:

- Horizontal density D_h [wale/50mm] and vertical density D_v [course/50mm] – were measured directly according to STAS 5903-68. With these values, the surface densities were calculated D_s [$N_{stitches}/2500\text{ mm}^2$].
- Thickness δ [mm] was determined according to STAS 6139/69.
- Mass per unit area M [g/m^2] was determined according to STAS 6040-79.
- Stitch length l [mm] was determined using the unravel method.

The values of structural parameters are presented in Table 1.

Table 1. The values of structural parameters

Sample	Horizontal density [wale/50mm]	Vertical density [course/50mm]	Surface densities [$N_{stitches}/2500\text{mm}^2$]	Mass unit area [g/m^2]	Thickness [mm]
100% Cotton - raw	31	37	1147	216	1.3
100% Cotton - dyed	34	39	1326	225.2	1.4
50/50% Cotton /PES - raw	33	35	1155	189.6	1.44
50/50% Cotton /PES - dyed	39	37	1443	220.8	1.46

3.2 Comfort characteristics of knitted fabrics

For the raw and dyed knitted fabrics, the following comfort characteristics were determined: the thermal resistance and water vapour resistance.

Thermal resistance R_t [$m^2 \text{K/W}$] and **water vapour resistance** R_v [$m^2 \text{Pa/W}$] were measured using the PERMTEST apparatus (Sensora, Czech Republic), similar to ISO 11092, based on the Fast Skin Model. The accuracy of the measures using this method is higher and the experimental data presenting a variation coefficient $CV \ll 3$.

The values of comfort characteristics for the raw and finished (dyed) knitted fabrics are presented in Table 2 and plotted in Figure 2 and 3.

Table 2. Values of thermal resistance R_t and water vapour resistance R_v

Sample	R_t [$m^2 \text{K/W}$]	R_v [$m^2 \text{Pa/W}$]
100% Cotton - raw	54.30	4.3
100% Cotton - dyed	68.93	4.6
50/50% Cotton /PES - raw	45.43	4.4
50/50% Cotton /PES - dyed	66.63	5.4

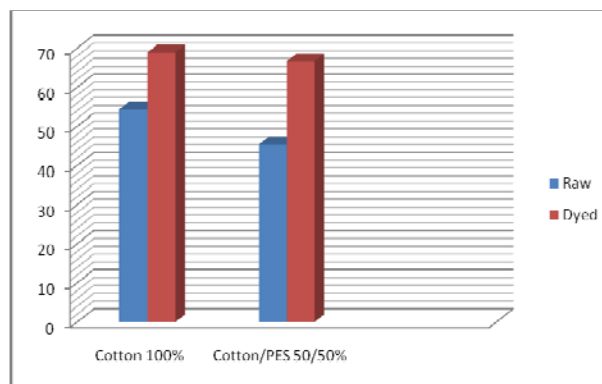


Figure 2. Changes of thermal resistance values for the raw and dyed knitted fabrics

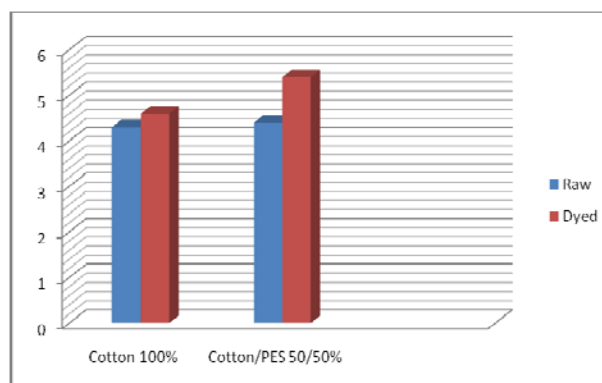


Figure 3. Changes of water vapour resistance values for the raw and dyed knitted fabrics

3. 3. Functional thermal field of analysed knitted fabrics

One of the most interesting problems which can be solved by using the numerical values of thermo-physiological characteristics is the determination of thermal field for the destination of analysed clothing product. This suggests the establishment of the minimum and maximum temperature values $t_{a,max}$ and $t_{a,min}$ of the environment in which the wearer may feel comfortable in terms of thermal transfer and moisture.

By scientific designing of clothing products which have to be functional in a wide range of environment conditions and physical stresses of the body, so that the wearer feels comfortable. In this way the product performs its thermo-physical function in correlation with the requirements assigned by the product destination [6].

To calculate the temperature values $t_{a,max}$ and $t_{a,min}$ characterising the thermal field (see Table 3), two thermo-physiological values were used (thermal resistance R_t [$m^2 \text{ }^\circ\text{K/W}$] and water vapour resistance R_v [$m^2 \text{ Pa/W}$]).

The clothing products worn directly on the skin represent the destination of dyed knitted fabrics for the warm season and for this reason the specific environment values were considered for the summer season (the average conventional temperature $t_e=25^\circ\text{C}$).

To establish the minimum and maximum temperature of thermal field, the calculus started from the energy balance equation [7].

$$M - L_m = Q_{res} + (t_s - t_a)F / R_t + d(p_s - p_a)F / R_v \pm \Delta S \quad (1)$$

Where:

- M - the metabolic heat production [W];
- L_m - the amount of energy consumed in the form of mechanical work [W];
- Q_{res} - the amount of heat lost through breathing [W];
- t_s - the mean temperature of skin [$^\circ\text{C}$];
- t_a - the environment temperature [$^\circ\text{C}$];
- F - skin surface [m^2];
- R_t - thermal resistance [$m^2\text{ }^\circ\text{C/W}$];
- d - discomfort factor (0,06÷1);
- p_s - saturated water vapour pressure from skin surface [mm.col.Hg.];
- p_a - partial pressure of water vapour from the environment [mm.col.Hg.];
- R_v - water vapour resistance [mm.Hg. m^2 /W];
- $\pm\Delta S$ - thermal variation [$^\circ\text{C}$].

Factor “d” represents the density of sweat covering the skin expressed in percentages. If the value of “d” is 0.1 this suggests that the sweating covers the skin in a percentage of 10% and the wearer feels no sweat. If the value of “d” factor is between 0.3÷0.6 this suggests that the wearer feels comfortable, because the skin is covered with sweat in a percentage of 30÷60% and the factor d equals by 1 means a skin covered by sweat (100%).

The limits of thermal field were established using the equation 2 and 3:

$$t_{a,min} = 32 - R_t[(M - Q_{res}) / F - 0.06(35.7 - p_a) / R_v] \quad (2)$$

$$t_{a,max} = 36 - R_t[(M - L_m - Q_{res}) / F - d(44.6 - p_a) / R_v] \quad (3)$$

The temperature range placed between the minimum and maximum value represents the thermal field of use (functional) of the analyzed clothing product and the values for the dyed knitted fabrics are summarized in Table 3.

Temperature $t_{a,min}$ was calculated considering that the wearer rests, situation that corresponds to minimal ventilation, while for $t_{a,max}$ the subject was considered to be moving and under physical strain.

If the wearer is resting, the following values must be taken into account [8]:

- 130 W metabolic energy;
- 32 °C skin surface temperature;
- 35.7 mmHg saturated vapour pressure at 32 °C;

From the energy balance equation the following terms of equation are neglected:

- The thermal flow of evaporation considering that the wearer rests and has a reduced sweating “ $d \gg 0$ ”;
- The thermal variation ΔS , because the amount of heat accumulated do not have to change;
- The mechanical work L_m .

If the wearer is considered to be moving, the following value must be taken into account:

- 36 °C skin surface temperature;
- 44.6 mmHg saturated vapour pressure from surface skin;
- The difference $M - L_m - Q_{res} = 600$ W;
- “ d ” factor $d = 0.9$.

The wearer was considered to have a standard body with 1.8 m² skin surface, 70 kg weight and 171 cm body height.

To establish the thermal field of clothing products produced from the analyzed knitted fabrics, $t_{a,min}$ and $t_{a,max}$ were calculated taking into account the value of thermal resistance R_t [m² °K/W] and water vapour resistance R_v [m² Pa/W] experimentally determined.

Table 3. The values for thermal field limits

Sample	$t_{a,min}$ [°C]	$t_{a,max}$ [°C]
100% Cotton - dyed	13.8	39.4
50/50% Cotton /PES - dyed	14.4	39.2

3. CONCLUSIONS

1. The research of this paper presents the influence of dyeing treatments on the values of comfort characteristics and structural parameters of knitted fabrics and the limits of the thermal field of these samples.

2. After the dyeing process, the values of thickness δ [mm], mass per unit area M [g/m²] and surface densities D_s [N_{stitches}/2500mm²] increased.

3. For the raw and dyed knitted fabrics made of 100% cotton yarns, the thermal resistance R_t [m² °K/W] and the water vapour resistance R_v [m² Pa/W] increases as a result of the fabric contraction, that increased values of thickness δ [mm], mass per unit area M [g/m²] and surface densities D_s [N_{stitches}/2500mm²].

4. Similar behaviour was registered for the raw and dyed knitted fabrics made of 50/50% cotton/PES blended yarns.

5. The values of thermal resistance R_t [m² °K/W] and water vapour resistance R_v [m² Pa/W] for both groups of fabrics (100% cotton, 50/50% cotton/PES) increase after dyeing treatment.

6. Functional thermal field can be modified by changing both the structural parameters and finishing treatments (dyeing), resulting new values for R_t and R_v .

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EXPERT STAFF- THE GREATEST POTENTIAL FOR ECONOMIC GROWTH OF THE TEXTILE INDUSTRY IN THE REPUBLIC OF SERBIA

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Keywords: Competitiveness, Textile industry, Management, Education, Knowledge

Abstract: *Serbian textile industry, as the textile industry in most countries in the process of transition, represents the significant area for development, especially if the foreign partners' interest is taken into account (availability of infrastructure, cheap labour force, vicinity of market and so on) besides the problems that exist for a longer period of time (old equipment, lack of financial capital, lack of innovation). Competitive advantage of Serbian textile industry must be based on innovation, quality, and advancement of technology and higher competence of workers. The greatest potential that would lead to faster economic development of textile industry is educated people, i.e. skilled staff. In order to improve the quality of business operations of domestic companies in the textile industry, colleges should educate personnel in accordance to European integration flows. Investments in education policy are safe guarantees towards accomplishment of growing market demands.*

The fast tempo of environmental changes requires people capable to respond to all challenges of modern business operations. Modern market concept of business operation requires harmonization of necessary knowledge and skills on each employee level. Modern society requires experts who have different kinds of knowledge and skills, first of all in the management and IT areas, who are capable of making decisions very fast, who show interest for implementation of new methods and techniques in business, and who seek the way to improve working process. This is the reason why education of every employee in textile companies represents a precondition for acquiring better business effects.

One of the most important problems of domestic textile industry companies, which conditions bad market appearance of our companies on the international market, is certainly inadequate knowledge usage, mainly regarding to the knowledge necessary for efficient management of a company. Projecting of adequate educational process will best satisfy the demand for the textile engineers of high competence for mastering and development of knowledge, capable of solving technical and management problems. That is why the engineers of textile technology are the most wanted to participate in defining technology management concept which is crucial for the growth and development of textile industry companies. The new operation field of textile

engineers spreads into management structures and starts to go beyond technical-technological knowledge and skills, and it requires multidisciplinary approach in business realisation.

Transition process has enhanced chronic problems of the textile and clothing industry companies in Serbia, and in order to define guides for improvement of business operations in this sector, the research has been conducted on the territory of Serbia, whose goal was to gain opinions of experts of different evocation and functions in textile and clothing industry, economy, education, scientific work, and in order to improve future development of textile and clothing industry and importance for the development of national economy. The research aims to identify all factors that influence the improvement of education of skilled staff in textile industry. During the identification and analysis of the existing situation, the need for improvement of business operation quality and quality of skilled staff in textile industry was perceived, in order to improve competitiveness of domestic textile companies.

1. INTRODUCTION

Human resources of high quality are the framework for acquiring and keeping competitive advantage in sometimes unpredictable and unstable conditions of business environment. In order to overcome economy crisis it is necessary to connect work and education, because a society that learns will be a society that works and vice versa.

The resources themselves do not provide the competitive advantage, but the company's ability to use them in a way that is superior in relation to competitors. Strategic development represents, in our social-economy conditions and transitional processes, permanent innovation of knowledge and skills as well as transmission of knowledge for new technologies, markets and processes, as well as knowledge for effacing the differences in market positioning in relation to the leaders or competitors.

The world's developed countries, instead of domination of natural and financial resources, redirect their development goals and strategies on domination of human resources, which demands alternation of present educational systems into rational and functional education. Competitive position of each business system on highly competitive market requires good and developed base of the employees, on which the growth and development strategy is based. Development and education of human resources based on the principles of lifetime learning and knowledge and skills innovation have become the challenge that each business system has to deal with eventually. Knowledge, as the result of development of the employees, has become strategic resource and source of competitive advantage in modern economy.

The term human resources signifies connected group of activities that provide socially determined goals, which are closely connected with education as global social activity, but it submits to general social interest. Education of human resources is dynamic process, which is constantly happening in a different way in different activities, because it is conditioned with working requirements, which further depend upon the nature and degree of applied technology. Present researches in the human resources management area show the importance of the employees in the achievement of the results and business goals, as well as understanding that human resources have become important competitiveness factors on the global commodity and services market. Comparative company's advantage in 21st century will be "Knowledge as resource", because that is the only way a company will be able to overcome the competition. Therefore, it is necessary to achieve efficient knowledge usage through innovative attempts (new products and processes). Knowledge is the basic resource that has influence on efficient usage of other company's resources, but also the only way to

survive in a modern environment. Human resources management is not only a strategic instrument, but it establishes sustainable competitiveness of an organisation. In order to achieve competitiveness through human resources, it is necessary to change the way a manager regards his employees and human

relations. Employees are regarded as partners, and not as costs which have to be reduced or avoided [1].

Modern business conditions impose the need for improvement of the training process for textile engineers. Technological development during privatisation, starting outlines of market economy on the one hand and IT development on the other hand require changes in the business organisation, strategic and operative planning and education of experts.

2. LEARNING AND KNOWLEDGE AS INNOVATION AND COMPETITIVENESS FACTOR

The only permanent source of competitive advantage of a company in modern business conditions is its ability to learn. Knowledge becomes basic resource of business operations, which provides three other resources: labour force, capital and natural resources, which have to be productive. Drucker expresses an opinion that “traditional resources” – land (natural resources), labour force and capital have become less important, because they can be easily acquired if one possesses knowledge. Knowledge will become strategic source of power and wealth in new society, and basic social group will be knowledge users, i.e. the persons capable of putting knowledge into function for business activity. Drucker calls them “knowledge workers”. This is the society where “responsibility for knowledge implementation and effect achieved in that way” replaces “responsibility for human effect”.

There is strong technical and technological progress in the modern economy. Companies, which apply such achievements, have advantage in market competition, [2].

Fast rate of changes in the surroundings demands people capable to respond to all challenges that modern business brings along. New business conditions require people to possess the following characteristics:

- Knowledge
- Learning ability
- Initiative
- Flexibility
- Involvement
- Experience [3].

Education and knowledge are new factors of concurrence. Every individual must constantly improve oneself and one’s knowledge. The group of such individuals, that constantly improve oneself and improve productivity of one’s knowledge makes the organisation productive. The fact points the new role of education – education must pervade the whole society. Education system must become open, dynamic, and offensive as the knowledge itself. Successful business of a company depends more and more upon knowledge productivity.

Riderstrale and Nordstrom state that “the foundations and sources of competitive advantage – knowledge, quality and people – must be the everyday issues for every employee”, [4].

Research conducted in Stanford University, which confirms these attitudes and at the same time forces on thinking, says the entire human knowledge, appeared until 1900, has doubled

until 1950, [5] and it doubles every 5-8 years. Since the quantum of increasing human knowledge influences, and will influence internal organisation and human behaviour, the companies will have to be prepared, open and capable to find out and accept new knowledge necessary for its business operations, and active and dynamic enough to apply the knowledge. The employees will have to adjust to the “deep knowledge” and impeccable specialisation in the area, which shall replace “wide knowledge”, where people know a bit of everything. In addition, due to erosion, knowledge depreciation where knowledge in 3-5 years gets old for 50%, the employees have to acquire new knowledge. Permanent education and training have important place in this set. This fact shows the new role of education – education has to pervade the entire society.

Successful business operations depend upon constant investment in learning and acquisition of new knowledge. Companies create new products and services and improve the existing ones by applying new knowledge. Knowledge represents key resource for the company development and basic way for acquiring competitive advantage. Establishment, sustaining and development of competitive advantage on the market depends upon the organisation ability to learn. Using knowledge as basic economy resource, organisations succeed in making other resources – labour force, capital and natural resources more productive, but it is necessary to constantly improve knowledge productivity.

Human knowledge and expertise, although difficult to quantify, represent the value-creating source for the buyers and owners. The great surprise for the economy sphere represents the fact that capital cannot replace people where knowledge is concerned. Therefore, it is important for the company’s survival in economy, to attract and preserve good and competitive workers, which represent the most valuable resource of the company. Economy, based on knowledge, has basis in constant learning and acquisition of new knowledge. In order to acquire new knowledge, the company opens its own educational centres, which have important role in training and development of capable workers.

Knowledge and learning encouragement significantly influences innovation of the company, because learning and knowledge represent significant factors of innovation. Innovation degree influences the acquisition of competitive advantage, and knowledge is the only permanent source of competitive advantage. Constant updating, improvement and enlargement of knowledge is necessary for the company’s development, and this is achieved by learning. The companies affirm importance of learning, which becomes a constant process. New knowledge is acquired as the result of constant learning. Knowledge acquirement is a process which should be accompanied by motivation. The company, which aims to achieve competitive advantage on market should innovate and learn in relation to the competition. A synonym for successful organisation is an organisation that learns, because it collects all available knowledge, experiences and intellectual resources in order to achieve good performances and values for its stakeholders.

The companies that constantly learn are forcing learning of their employees through constant interaction, team work and communication with the environment. People should know that learning is a constant process, but they should be constantly motivated, encouraged and impelled to think systematically and to learn from each other. Learning and acquisition of new knowledge represent the change for the employees. The employees are usually resistant to changes. In order to avoid misunderstandings, the change should be presented to the employees in a way that is acceptable for them, importance of the changes for them and entire company should be explained. The task of a manager is to create an environment for learning where the employees shall compete in acquiring new knowledge [6].

It is necessary for the company to increase its knowledge base in order to preserve competitive advantage and to be able to constantly innovate i.e. to follow the dying and

creating of an innovation. Besides knowledge as the company's value, intellectual capital encompasses all non-material values and represents competitive tool of each company on the market. Knowledge represents only one segment of intellectual capital of a company.

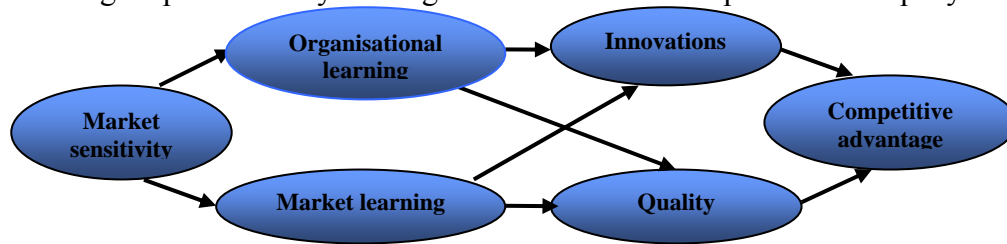


Figure 1. Learning process for creating competitive advantage, Source [6]

3. EDUCATION OF THE EMPLOYEES IN TEXTILE INDUSTRY AS PRECONDITION FOR ACQUIRING COMPETITIVE ADVANTAGE

Investment in the employees is regarded as investment in future, acquisition of competitive advantage on the market and provision of comparative advantages. Many companies apply continuous learning, which requires understanding of the entire working system from the employees, including connections between their jobs, working units and the company. Managers have active roles in recognizing the employees' need for training. Constant education is one of the most important forms of management and development of human resources nowadays. Modern companies dedicate more of their resources (money, time, information, energy and alike) to education and constant training of the employees. Management understands that constant education and specialization of the employees are the most effective ways of competitive advantage, based upon assumptions of entrance in market game and fight with competition for consumers' trust and inclination [7].

Successful organizations have to build their future on efficiency and top performances of all their units. It requires higher collective intelligence based upon knowledge, ability and understanding. Such organization that learns faster than the competition can be called or described as learning organization. Modern companies are becoming learning companies not because their managers and employees love to learn but because it is the only way to survive in modern environment.

The term "learning companies" has been used for a long time. These are the companies in which the employees constantly try to learn new things and apply learned things to improve quality of a product or service. The companies that try to become learning organizations usually change their structure into organizations that work in teams, shaping of smaller business units or profitable centres, which must collect and exchange knowledge and decision-making needed for better services or products.

Some companies go a step forward and define which part of working time shall be used for the employees' education, 10% or 50%, depending upon the position the employee covers, as well as organising various courses within the company. New knowledge and new technologies, some of which unknown upon hiring require constant training. Training of the employees enables one to discover and activate working and human resources, and motivate and direct it in a proper way. Managers define necessary courses for each employee, based upon assessed ability of the person. Environment of a modern company demands constant learning, accommodation and innovation, independence, responsibility, self-development and readiness to take risks. This is why people but not technology or structure makes a company

successful. Optimal usage of personnel potential in an organisation enables realisation of advantage on the market.

The structure of a learning organisation is based upon the concept of continuous improvement, and management of quality is built into all processes and working manners.

Greater competition on the market and harder survival in present business operations engage the companies in learning and acquisition of new knowledge. Innovators make leading position on the market and they constantly learn. Traditional organisations, based upon central regulation and product orientation, have been replaced with modern organisations, which are focused on learning and acquisition of new knowledge, are based upon intelligent leadership and represent the organisation of the future. Learning organisation is an organisation which enables learning for its members and experiences continuous transformation. It provides a chance for the employees to constantly expand their capacities in order to achieve the results they really want.

The only source of competitive advantage of a company on the market is its ability to learn constantly. Companies are more competitive because they learn more and know more than

competition. The aim of organisational learning is to expand knowledge and to make it available to all members of the organisation [8].

In modern market conditions, the only permanent source of competitive advantage of a company is in its ability to learn. Modern market business operation of textile companies is characterised by unfavourable aspects which are seen in a bad position of textile companies on the global market scene, decreased competition, lack of technology, insufficient training of the employee and lack of standard. In that sense, the main acting fields to improve quality of business operations of domestic textile industry companies are improvement of business operation quality and improvement of managers and employees' knowledge.

Significant and maybe even crucial responsibility for existence and development of these companies are in the domain of leadership and skilled workers. The leadership's responsibility is primarily creating the company's policy and strategy and simultaneously influencing on motivation, development, communication and behaviour of skilled workers. The skilled workers' responsibility is reflected in constant education and innovation of knowledge and skills. In that way, the preconditions for successful technology management are created, which is crucial for the company's growth and development as well as for the industry. Industry has the need and obligation to invest in highly educated workers that shall apply and develop new technological achievements. The experts that should develop and work with high technologies as well as those who create the strategy of technological growth and carry out the research-development functions are mainly textile technology engineers.

The series of demands are set before professional staffs to permanently innovate their knowledge and skills. Modern market concept of business operations requires improvement of necessary knowledge and skills on every level of the employees.

Significant and maybe even crucial responsibility for existence and development of these companies is in the domain of leadership and skilled workers. The leadership's responsibility is primarily creating the company's policy and strategy and simultaneously influencing the motivation, development, communication and behaviour of skilled workers. The skilled workers' responsibility is reflected in constant education and innovation of knowledge and skills. In that way, the preconditions for successful technology management are created, which is crucial for the company's growth and development as well as for the industry. Industry has the need and obligation for investing in highly educated workers that shall apply and develop new technological achievements. The experts that should develop and work with

high technologies as well as those who create the strategy of technological growth and carry out the research-development functions are mainly engineers of textile technology.

It is very important that the right people perform the given task and each employee is given the opportunity to specialise until they are capable of performing the job. Previously it is necessary to analyse structures of professional capabilities of the employees in textile industry and after that to develop the concept:

- for permanent knowledge innovation of every employee
- for introduction of obligatory courses in modern achievements significant for textile technologies
- for introduction of short courses in basic knowledge form accounting, finance, management, quality management, business law and computer science
- for introduction of adjusted courses in human sciences such as philosophy, art psychology, foreign languages and alike.

Textile technology engineers, according to their basic education, are first called to participate in technology management concept, which is crucial for the growth and development of these companies. The new action area of textile engineers goes into management structures, starts to overpass technical-technological knowledge and skills, and requires multidisciplinary in work realisation.

Education of every employee in textile companies is a precondition for the acquisition of better business effects – better knowledge and skills in computer science and management is pointed out as well as using foreign experiences.

Thorough restructuring of educational system is necessary. Thorough reforming and rationalisation of educational system, according to the textile sector development in the world is necessary as soon as possible, because there is a great deficiency in adequate personnel on all levels from artificer to executive managers.

The new market business concept shall require from leadership and especially skilled workers to possess:

- Multidisciplinary in integrating textile technology knowledge and necessary marketing, management, ecology, psychology and sociology knowledge;
- Ability to use modern techniques and skills as well as engineering tools;
- Work inventiveness;
- Management innovativeness;
- Flexible behaviour;
- Positive appearance and other.

Lack of personnel with modern abilities influence the efficient development of textile sector (growth of national product, competition, better strategic position, technological modernisation, business modernisation and other modernisation) and because of it, education of every employee is precondition for business productivity. In future, textile and clothing industry will be able to survive and do business successfully only if the business policy is applied. The business policy must be oriented toward demand requests, flexible – to adjust to the eventual changes, able to meet consumers' specific requests and able to switch to other production type swiftly and easy. It also must follow new technological and management innovation.

Textile engineering is in the group of progressive sciences and is the most important part of technological development, and constantly alters and improves, the skilled workers constantly and intensively train and innovate their knowledge and skills.

On the other hand, successful company management in nowadays conditions means successful technology management. Clearly defined technology management concept is

crucial for the growth and development of the company and economy. Technology management and appropriate technological development strategy on the national level should provide the creation of rational and efficient economy.

In that way, transitional flows in the society, especially in business, gain appropriate orientation. Technological development in transition, initial outlines of market economy on the one hand and development of information technologies on the other hand, demand alternations in the organisation itself, and strategic and operative planning as well as education of future specialists.

4. RESEARCH RESULTS ON PROFESSIONAL PERSONNEL EDUCATION IN TEXTILE INDUSTRY IN SERBIA

One of the most common problems of domestic economy, which mainly causes bad market appearance of our companies in international markets, is certainly inadequate use of knowledge, primarily of knowledge necessary for successful company's management. Domestic companies have problems with implementing modern management methods and techniques in business for years. Increase of professional and creative efficiency of studies, less duration of studies, higher mobility and chances for students to pass on higher levels and forms of education and specialisation, continuous science monitoring and skill acquisition, adjustment of educational profile and improvement of scientific knowledge and adjustment of our educational system with demands of professional work are expected from reformed educational system. Bologna Declaration insists on educational development and improvement of scientific knowledge,

acceptance of European standards along with reform and adjustment of our educational system.

For this purpose, the analysis of student attitudes as users of college services, to define necessary knowledge and skills needed for textile industry experts in conditions of market business operations, is provided, but also specific demands of the experts for knowledge improvement and education of professional personnel in textile industry. Conducted research aimed to define all factors that influence the improvement of professional personnel in textile industry.

Identifying all factors that have influence on educational improvement of professional personnel in textile industry was the aim of conducted research. When the existing situation was identified and analysed, it was necessary to improve business quality as well as professional personnel quality in textile industry in order to improve competition between domestic textile companies that are experiencing problems with competitive ability for several years. The research of experts' attitudes was conducted on Serbian territory in order to gain expert opinions of various professions and functions in textile industry, economy, education, scientific and research work and students of textile faculty.

Domestic experts are unique in contributing the development of domestic industry. Experts and students respondents share the same opinion that textile organisations must trust textile engineers that have finished our colleges and faculties. Most of the expert respondents (80%) as well as most of the student respondents (73%) think that textile organisations must trust textile engineers that have finished our colleges and faculties. Most of expert respondents (64%) think that the existing educational profile on domestic faculties can prepare engineers for the challenges of economy in transition. The experts that gave affirmative answer on the previous question said that the most important reasons why

domestic faculties can prepare engineers for the challenges of economy in transition are multidisciplinary (52.08%), theoretical basis (33.33%) and innovativeness (14.58%).

Regarding the research, there were some interesting results concerning the way that a textile engineer is perceived in the future, and domestic experts see him as Textile and clothes designer (32.26%), Knowledge worker (30.65%) and Techno-manager (27.42%), but only 9.68% perceive him as the Development researcher.

More than half of expert respondents (54%) think there is insufficient number of professional subjects necessary for professional specialisation. In order to improve their educational plans and programs the experts suggested the colleges the following: compulsory expert practice (26%), creating the possibility for visiting or conducting expert practice in foreign countries (15%), introduction of new professional subjects (15.07%), intensive cooperation with organisations concerning new information (11.64%), employing domestic and foreign experts to teach professional subjects (10.96%) and introduction of new management contents (8.89%).

The experts think that knowledge (40.40%), capability to learn (21.21%) and initiative (12.12%) are the most important characteristics that new business conditions require of a textile engineer.

The education of every employee represents the precondition for achievement of better business effects, and mainly business productivity improvement. As one of the main factors that can improve competitive ability and business of our textile companies is wider appliance of quality management concept, and the precondition to do this is the improvement of employees' knowledge in our companies, especially of executive managers, managers and company owners [9].

The analysis of the need for educating the textile engineers that now work in the textile industry companies shows that the education must necessarily be conducted in the following areas: Accounting and Computer Science (28.35%), Foreign Languages (16.54%), Management (16.54%), Design (11.02%) illustrated in the Table 1.

Table 1. The need for educating the textile engineers that work in the textile industry, Source [10]

No	Name field	%
1.	Foreign languages	16,54
2.	Computers and informatics	28,35
3.	Marketing	9,45
4.	Management	16,54
5.	Design	11,02
6.	Entrepreneurship	3,94
7.	Quality management	14,17
Σ		100

Competitive advantage of Serbian textile industry must start from innovation, quality to technology improvement and larger workers competence. Educated people are the biggest potential that would lead to faster economic development of textile industry, [11].

The main factors of achieving the competitive advantage of textile industry companies are shown in the Table 2.

Table 2. The factors of competitive advantage of textile industry companies, Source [10]

No	Factors of competitive advantage	%
1.	Improvement of employees' knowledge	32,29
2.	Privatisation	18,75
3.	Implementation of quality management concept	16,67
4.	Attracting the foreign investments	12,50
5.	Development of small and middle companies	11,46
6.	Cluster development and its association	7,29
7.	Fast trend adjustment	1,04
Σ		100

The responsibility of professional personnel in textile industry is seen in constant education and training of constant education principle and knowledge and skills innovation. Preconditions for successful technology management are created in such way, which is vital for growth and development of these companies and specific economy sector.

In order to improve quality of domestic companies business in textile industry, colleges should educate professional personnel in accordance with European integration flows. The existing education profiles on domestic faculties are able to prepare textile engineers for challenges of economy in transition, and textile companies can trust the textile engineers that have finished our colleges and faculties.

5. CONCLUSION

Modern tendencies of the countries' development in market economy show that education and training of human resources are top priorities in national strategies and policies of social,

economic and technology development. Knowledge investment, that is, appropriate human resource procurement that is able to adjust to the alternated circumstances, obtains investment character, and education policy is not just human fund creation policy but also part of the entire society's development policy.

Education and creation of human resources is one of the most important instruments in creating strategy and policy of economy growth. The employees in modern organisation are required to be efficient, productive, and creative and to work well, and to achieve all goals, to possess a series of abilities, knowledge, personal features, skills and motivation. Learning is not only organisational function in modern organisation; it is involved in all processes, structure and organisational management. The degree an organisation can learn may become important competitive advantage, and lifelong learning and knowledge expansion is the main task of the employees.

Each country aspires to reach strategic aims in economy but also in other sectors. It especially refers to the education on all levels. Investments in education are safe guarantees for meeting the markets needs. Therefore, most of the countries are conducting continuous education on all levels and personnel structures in order to harmonise the more rigorous conditions of European community. It is necessary that college and faculties harmonise their education plans and programmes in accordance with Bologna declaration.

Even though Serbian economy is suffering from temptations of transition and transformation from state to economic market, and private initiative and ability, it has huge natural resources and knowledge, and must educate managers and technicians that will lead national economy. Education of every employee in a textile company represents precondition for acquiring better business effects – especially the need for better knowledge and skills in computer science and management is emphasized as well as usage of foreign experiences. The responsibility of professional personnel in textile industry is perceived in constant education and training of constant education principles and innovation of education and skills.

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EFFECT OF CATIONIZING ON NATURAL DYEING OF COTTON WITH MADDER AND TURMERIC

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Key words: Madder, turmeric, cationisation, natural dyeing, cotton

Abstract: *Natural dyeing of textiles has a very important place in human history. Mankind has dyed fabrics in unique colours with dyes from nature since ancient times. Natural dyeing draws attention nowadays due to growing environmental concerns. This study is aimed at improving dyeing stuff efficiency with limited resources. For this purpose, cotton fabrics were cationised with a cationic reactive dye fixing and soaping agent. Madder (*rubia tinctorum*) and turmeric (*curcuma longa l.*) were chosen as natural colorants. Changes on fastness properties were investigated.*

1. INTRODUCTION

Madder is a plant from rubiaceae family. It has been an important dyeing plant until late 19th century. The roots of this plant contain various dye stuffs like rubierithryn acid, rubiadin glucoside, purpurin and ksantopurpurin. The main dyestuff is rubierithryn acid which is the glucoside of alizarin. The chemical structure of alizarin is 1,2-dihydroxyanthraquinone shown on Figure 1. Alizarin can dye cotton, wool and silk. It may give foremost red and various colours with different mordants [1-2].

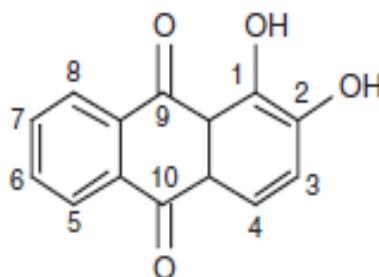


Figure.1: Dihydroxyanthraquinone [2]

Turmeric (*curcuma longa*) is a spice with various properties. The main colorant constituent is curcumin in turmeric. Curcumin is used to obtain yellow shades. The rhizomes of the plant are the main resource of curcumin [3]. The chemical structure of curcumin is shown on Figure 2.

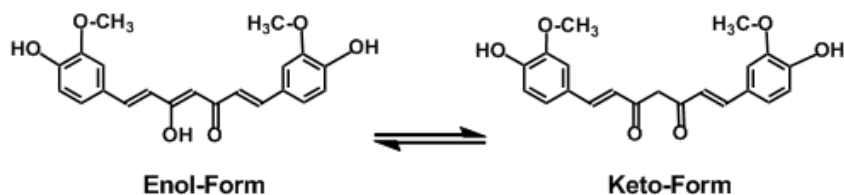


Figure 2: Curcumin (enol and ketoform) [9]

Most natural dyestuffs cannot bond with fibers, so mordant chemicals are generally used to provide affinity between the fibres and the dyestuffs. Metal salts are suitable for mordant materials [4]. Mordanting can be performed as premordanting, simultaneous mordanting and post mordanting. Different colors may be obtained from the same natural dyestuff by using different mordants or mordant combinations. Also different mordant materials may also affect fastness properties [5].

Hydroxyl groups of cellulose are charged negatively in the presence of water. This fact gives cellulose molecules anionic character [6]. Therefore, cationizing of cotton improves dyeability; affinity between the fiber and the dye increases by cationisation [7].

2. EXPERIMENTAL PART

100% cotton plain woven fabric was used. Madder and turmeric were chosen as natural dyestuff sources. Powders' extraction was used for dyeing. 1/1 plant/fabric ratio was carried out. Alum was used as mordant material via premordanting method. Twenty percent alum used for mordanting. A reactive dye fixing and soaping agent (Laucol RW, Günerca) was used as cationizing agent. Cationizing and mordanting are applied at the same bath for 30 minutes at 80°C. A laboratory type exhaustion dyeing machine (COPOWER, SandoLab) was used for dyeing, mordanting and cationizing. Samples were dyed at 100°C with 1:40 liquor ratio. 100% madder extraction, 100% turmeric extraction and 50% madder - 50% turmeric extraction was used for dyeing cotton samples. Cationised and un-cationised fabrics were compared for each sample. Colour measurements were carried out using DataColor 600 spectrophotometer. Wash fastness and light fastness properties were investigated according to ISO 105 C06 standard and ISO 105 B02 standard, respectively.

3. RESULTS AND DISCUSSION

3.1. Colour Properties

Dyed samples are shown on Figure 2.

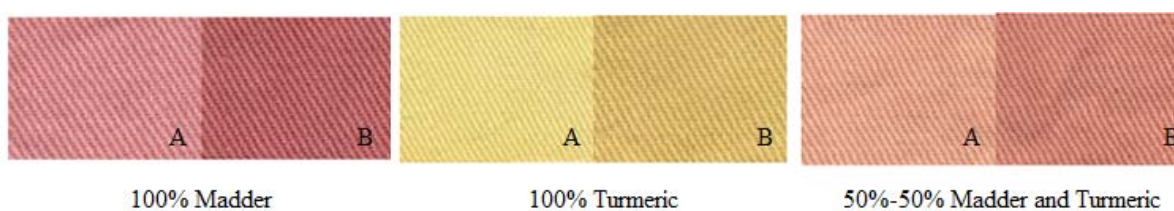


Figure 2: Samples dyed with madder and turmeric (A: Not cationised, B: Cationised)

Obvious colour differences between the cationised and un-cationised samples can clearly be seen from Figure 2. CIELAB colour data confirmed this visual judgement. Colorimetric properties of dyed samples are shown on Table 1 and Figure 3.

Natural Dye / Cationization	$f(k)$	L^*	a^*	b^*	C^*	h°
Madder	12.0	66.6	25.8	11.2	28.1	23.6
Madder (Cationised)	31.6	53.6	29.3	13.2	32.1	24.3
Madder + Turmeric	10.9	72.5	17.2	25.4	30.7	56.0
Madder + Turmeric (Cationised)	23.5	60.9	23.4	22.8	32.7	44.3
Turmeric	11.7	84.7	-0.8	52.8	52.8	90.9
Turmeric (Cationised)	19.5	73.7	3.0	45.3	45.4	86.2

Table 1: CIELAB colorimetric data of dyed samples

Cationising process changes all colorimetric properties. It is clear from Table 1 that $f(k)$ colour yield values are increased with cationising. For example, colour yield value is increased approximately 163% on 100% madder dyeing after cationization. Therefore, higher colour strength is achieved with cationisation for all samples studied.

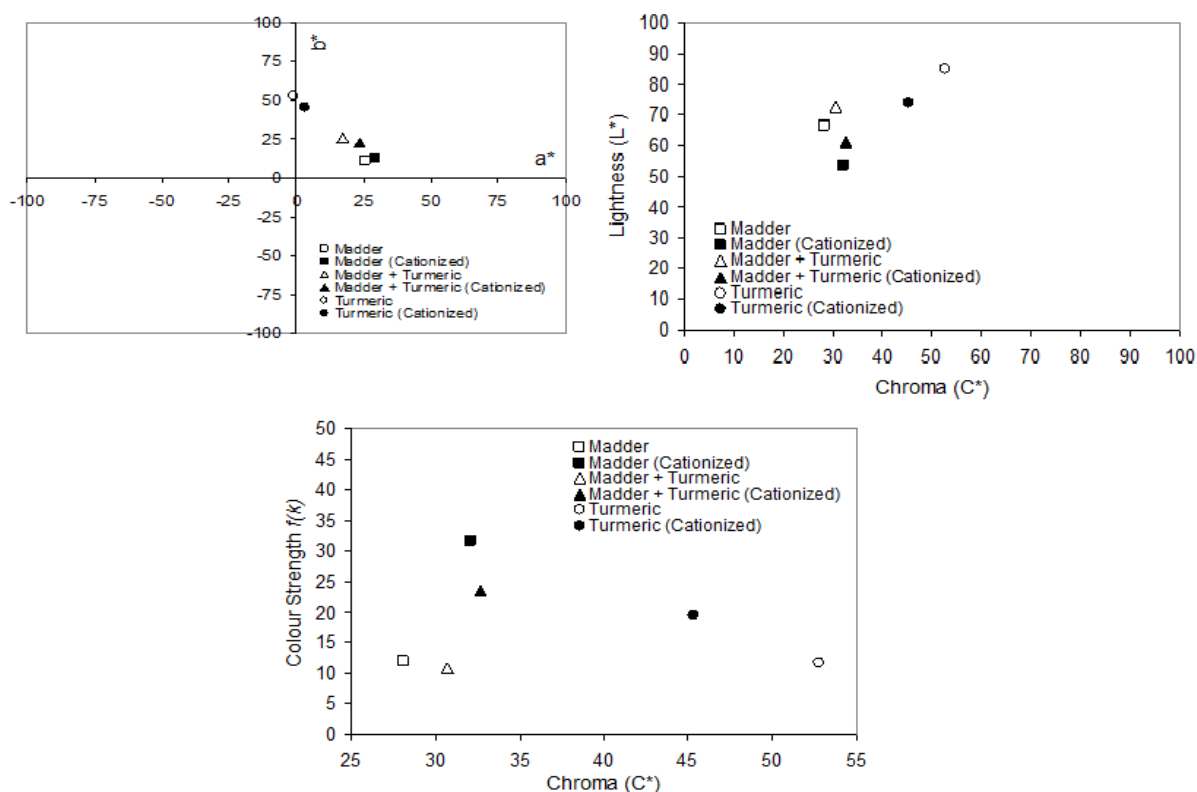


Figure 3: Colour Properties

Darker tones were obtained by cationising according to L^* values. For instance, lightness value (L^*) is decreased approximately 20% on madder dyeing after cationisation. So cationising results in higher colour strength and darker appearance.

3.2. Wash Fastness

Sample	Wash Fastness (C06 A2S) (staining on polyamide, cotton and acetate)		
	Polyamide	Cotton	Acetate
100% Madder	4-4/5	4/5	5
100% Madder with Cationising	4-4/5	4/5	5
50%-50 Madder-Turmeric	3/4	4	4/5-5
50%-50 Madder-Turmeric with Cationising	3/4	4	4/5-5
100% Turmeric with Cationising	3	3/4-4	4/5
100% Turmeric	3	3/4-4	4/5

Table 2: Wash fastness values

Colour yield values of cationised samples were higher (Table 1), however cationised and non-cationised samples have the same wash fastness values.

3.3. Light Fastness

Light Fastness values are shown on Table 3.

Sample	Light Fastness (Xenon) (1-8)
100% Madder	2
100% Madder with Cationising	3
50%-50 Madder-Turmeric	2
50%-50 Madder-Turmeric with Cationising	2,5
100% Turmeric with Cationising	1
100% Turmeric	1

Table 3: Light fastness values

Cationisation shows positive effect on light fastness of madder and madder + turmeric dyeings. These results were in line with the colour yield values. Since cationisation causes higher colour yield (Table 1) and higher light fastness (Table 3) results. Cationisation exhibits no improvement on light fastness value for turmeric dyeing. 100% turmeric dyeing has light fastness value of 1 for both cationised and not cationised samples.

4. CONCLUSION

The effect of cationisation on textile dyeing is an important issue for researches. Many studies are carried out to improve fastness levels and colour properties by cationisation. In this study, cationisation combined with natural dyeing. Cationisation of cotton fabric for madder and turmeric natural dyeing exhibits positive effect on colour fastness and colour properties.

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CLUSTER FORMATION IN THE TEXTILES FIELD

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Keywords: cluster, cluster formation, innovative cluster, cluster development strategies, textile clusters

Abstract: *In a modern world dominated by change and undergoing acute economic crisis, clusters are perceived as a path to success. Cluster companies can access qualified workforce, thus minimizing the costs of training people in various fields and of acquiring knowledge and technology needed to successfully compete in the market.*

Clusters prove that cooperation is possible between competing organizations provided they find a mutually beneficial way to cooperate that is based on a win-win approach.

This paper presents the stages of cluster formation and the elements of such a process aimed at achieving efficient organization, as well as new strategies for cluster development in comparison with current development strategies.

1. INTRODUCTION

A cluster can be defined as a group of several companies that are all active in the same field or in connected fields and that take common actions in a collaboration that is mutually profitable and leads to increased efficiency and access to the global market. A cluster type of organization facilitates the development of *investment strategies* that are mainly directed towards building knowledge based competitive advantage.

Flexible organization is a characteristic of clusters: each company carries on specific activities, depending on the market requirements and the cluster strategies. There are frequent changes in the production, gathering, use, storage, protection and selling of the cluster generated knowledge.

Information plays a major role in a cluster, and it is both a resource and a key product of the group of companies that are part of the cluster. Within a cluster the companies have access to qualified work force, they minimize training costs in various fields and the costs of the acquisition of knowledge and technology needed for success on the market.

2. CLUSTER FORMATION

Cluster formation unfolds in the following stages:

a) Analysis: statistical analysis, company interview, expert opinion, opportunity reporting;

- b) Preparation: consultations, information meetings, discussions, planning, debates;
- c) Strategy: elaboration of directions, communication, consultation, branding, coordination;
- d) Organization: professional training, human resources;
- e) Action: projects, cooperation, facilities, improvement.

A diagram of an innovative cluster is presented in Figure 1.

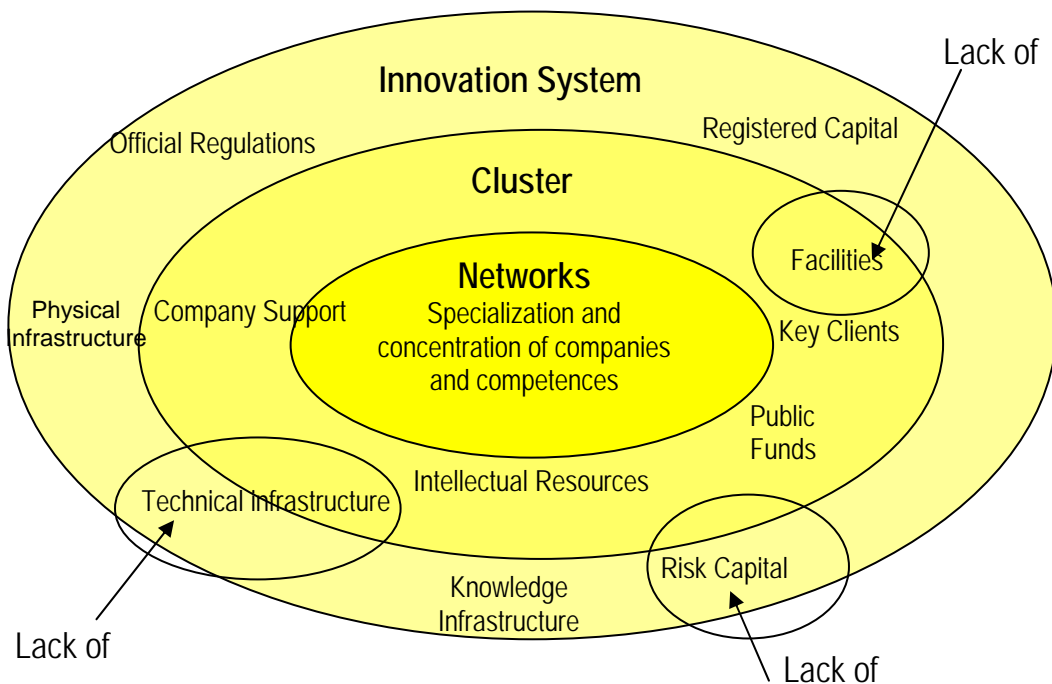


Figure 1: Innovative Cluster Diagram

Cluster formation is facilitated by the following *actions*: analysis completion, vision communication, strategy implementation, application of the action plan, meetings between the persons involved and cluster shaping. Cluster formation is also supported by neutral communication, good listening abilities, good interpersonal skills and the experience in multiple sectors.

Table 1 is a synthetic presentation of the relations between the elements of cluster formation that contribute to an efficient organization.

Table 1 Elements of efficient organization

Facility	Operations (results)	Exploration
Strategic Purpose	Cost, Profit	Innovation, Development
Critical Task	Efficiency, Incremental Innovation	Adaptability, New Products, Radical Innovations
Competence	Operational Ability	Entrepreneurial Abilities
Structure	Formal and Mechanical	Adaptable, Subtle
Control, Reward	Limits, Productivity	Demarcation, Development
Culture	Efficiency, Low Risk Quality, Clients	Risk Acceptance, Flexibility, Experimental Character
Management	Authoritarian Bureaucratic Type	Vision and involvement

Efficient management relies on the integration of teams that share experience, vision and values, as well as rewards for all the players involved.

From a general perspective, cluster development depends on the following *critical factors*: communication skills, the capacity to lead and to manage the process (facilitators), comprehensive development strategy, trust in cluster formation and cooperation advantages, common vision on the advantages of regional economic development, good relations between local administration, business environment and research and development institutions.

It is worth noting that the evolution of clusters starts with an initial grouping of usually small companies located in the same geographical area. However, there is a tendency to spatial expansion while the geographic barrier though still important is not an insurmountable barrier in their development. The more a cluster focuses on information the less important the spatial factor becomes.

A company that integrates a cluster structure can elaborate and develop a *new strategy* that is different from the classical strategies (see Figure 2).

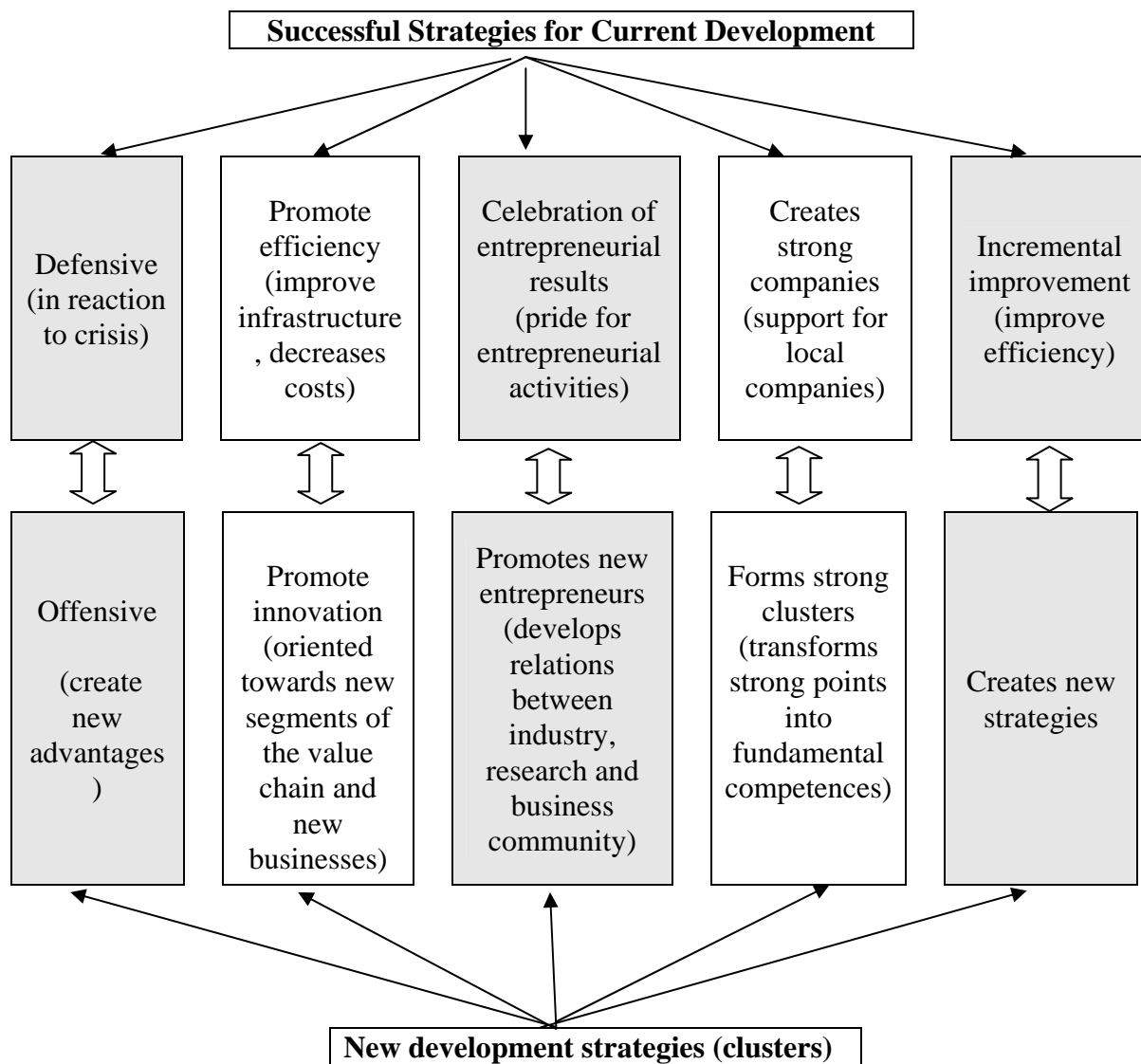


Figure 2 Characteristics of current development strategies and new development strategies related to clusters

The role of clusters in promoting innovation and economic development in Romania is connected to EU accession and the existence of Euro-regions. Most of the local development strategies currently under completion have as one of their objectives the studies for the identification of fields of interest for the development of regional clusters and measures to support them.

To define cluster success the classical theory of clusters introduces the concept of <triple helix> and assumes obligatory cooperation of the business environment, academic and research institutions and local authorities. The quadruple helix is an improved variant of this concept that seems to be suited for Romania and it is formed by adding institutions that act as catalysts in the general innovative process.

3. CLUSTERS IN TEXTILE INDUSTRY

According to common perception, the *textile industry* is a traditional sector, as any national industrial development includes this sector at its very start.

Given the fact that small and medium enterprises that are common to the textile industry do not have the strength to gain a position on the global market on their own, they can organize in clusters that are advantageous environments for business cooperation, commercial information, communication and legal issues.

Romanian textile companies should better give up the advantage of low labour costs and try to position themselves in the medium to high segment of the external market corresponding to high quality and strong brand image that are achievable by substantial investment in design, marketing and promotion.

Therefore, only strong and unified industries shall have access to investment resources. Hence clusters can represent a solution.

Currently there are 3 developing textile clusters in Romania.

ASTRICO NE is the *cluster* in North East region. ASTRICO is a producers' association established some time ago, a powerful production and commercial industrial group in the field of knitted fabrics. The cluster is organized around Rifil, the most important yarn manufacturer in Eastern Europe. The group's production is to a great extent exported on the European market and comprises 10 enterprises: one spinning mill representative for the Romanian industry – RIFIL and 9 producers of knitted fabrics and knitted garments.

Traditii Manufactura Viitor (Traditions Manufacture Future) - *TMV South – East* is the cluster in the South – East Region. This cluster focuses on activities and products that involve high levels of creativity and technology, on the increase of awareness and the consumer's interest in the fashion phenomenon, personnel stability and training, involvement of new companies and creation of a regional brand.

Romanian Textile Concept is a cluster in the Bucharest – Ilfov Region and consists in 18 partners and is formed around an association of 10 traditional producers active in the garments, knitted fabrics and leather industry.

4. CONCLUSIONS

The clusters generate economic value for both the cluster's members and the public benefit because of the high levels of efficiency, innovation and professional training. In a world dominated by change and going through economic crisis clusters are perceived as success models.

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ENVIRONMENTAL IMPACTS OF NATURAL DYEING OF POLYESTER WITH MADDER

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Keywords: COD, TOC, madder, natural dyeing, PET, chemical mordant, natural mordant

Abstract: *Environmental concerns are at the highest level today that have never been before and textile dyeing industry is a subject of ecological criticisms due to the heavy chemical load in the waste water. This situation leads people to investigate 'greener' ways of textile coloration. One of the suggestions is the natural dyeing of textiles. It is believed that natural dyeing is an environmental friendly textile coloration method; however, chemical mordant usage in natural dyeing is mostly not considered. In this study, 100% polyester fabrics were dyed with madder. 2 chemical and 2 natural mordants were used for dyeing along with the control without any mordant. The pH values, suspended solids (SS), the spectral absorption coefficient (SAC) values, total organic carbon (TOC), chemical oxygen demand (COD), and electrical conductivity (EC) properties of dyebath effluents and the colour properties of dyed polyester samples were determined.*

1. INTRODUCTION

Synthetic dyes are extensively used in many industries, such as: textile, leather, cosmetics, pharmaceutical, paper production, pulp manufacturing, printing, food production etc. to color their products. In recent decades, it is estimated that more than 100,000 dyes are available commercially ¹ and their global production exceeds 800,000 tons per year ². Approximately 15% of this production is discharged into wastewater or rejection operations during the manufacturing of colored products ³. The presence of dyes in water is undesirable; a very small amount of these coloring agents is highly visible and may be toxic to the aquatic environment ⁴⁻⁶. Dyes absorb and reflect sunlight entering the water and so they can interfere with the growth of bacteria and hinder photosynthesis in aquatic plants ⁷. In addition, some dyes or their metabolites can be toxic or mutagenic and carcinogenic to natural life or living organisms ^{8,9}.

Wastewaters of textile finishing sector, especially dye-house effluents, contain different classes of organic dyes, chemicals and auxiliaries, thus they are colored and have extreme pH, high COD, high temperature, AOX values, low biodegradability, and they may contain different salts, surfactants, heavy metals, and others. Therefore, dyebath effluents have to be treated before being discharged into the environment or municipal treatment plant ¹⁰.

Madder is a worldwide well-known dye plant especially for red colors. Its CI code is Natural Red 8¹¹. In different researches, 36 anthraquinones have been detected so far in madder roots as colorants¹². Farizadeh et al. ¹³ exhibit that alizarin, purpurin and quinizarin are the most common anthraquinone components in madder roots.

In this study, PET fabric was dyed with madder and the environmental effects of dyebath effluents were investigated. The pH values, suspended solids (SS), the spectral absorption coefficient (SAC) values, total organic carbon (TOC), chemical oxygen demand (COD), and electrical conductivity (EC) properties of dyebath effluents and the colour properties of dyed polyester samples were determined.

2. EXPERIMENTAL PART

2.1 Dyeing Procedure and Collection of Dyebath Effluent Samples

100% PET knitted fabric was naturally dyed with madder. Madder roots in powder form were processed with 100°C water for one hour to obtain dyeing liquor extraction and 1/40 plant/water ratio was carried out for that procedure. Simultaneous mordanting method was chosen. Two chemical (iron (II) sulphate, potassium bitartrate) and two natural (oak wood ash, black tea) mordants were applied and one control dyeing without mordant was carried out. Dyeing was performed at 100°C for 45 minutes in 1/40 liquor ratio. Dyebath effluent samples were collected after dyeing.

2.2 Chemical Analyses of Dyebath Effluents

The dye-bath with or without fabric effluents or wastewaters were analyzed for pH values, suspended solids (SS), the spectral absorption coefficient (SAC) values, total organic carbon (TOC), chemical oxygen demand (COD), and electrical conductivity (EC).

COD was measured using closed reflux method. Suspended solids (SS) concentration was measured using gravimetric method. Samples pH and EC values were determined with a WTW Inolab pH-meter and a WTW Conductimeter, respectively. The TOC content of the samples was measured with a Shimadzu TOC-V_{PCN} carbon analyzer equipped with an autosampler. Before TOC analysis, samples were pre-filtered with 0.45 µm membrane filters. The color was measured by determining the SAC of 0,45 µm filtered samples at three different wavelengths (436 nm, 525 nm, 620 nm) using a UV/Vis Lambda spectrophotometer (Perkin Elmer) as prescribed in EN ISO 7887. All analyses were performed according to Standard Methods¹⁴.

3. RESULTS

3.1 Results of dyebath effluents analyses

Wastewater from the textile industry contains high concentrations of organic and inorganic chemicals and is characterized by strong color and high total organic carbon (TOC) and chemical oxygen demand (COD) values¹⁵.

In the analyzed dyeing sample, highly contaminated concentrations obtained were shown in Table 1. In dyeing without mordant, COD and TOC values were obtained 13078 and 2914. Iron (II) sulphate gives the highest COD and TOC values (Table 1). These results are negative from environmental point of view.

Mordant Name	COD (mg/L)	TOC (mg/L)
Without Mordant	13078	2914
Potassium bitartrate	11906	2082
Iron (II) sulphate	13971	3664
Black Tea	13184	3067
Oak wood ash	13034	3239

Table 1: COD and TOC values of dyebath effluent

On the other hand, potassium bitartrate exhibits the lowest COD and TOC values. Potassium bitartrate results in %14 less COD and %23 less TOC than Iron (II). COD and TOC values of two natural mordants were in between these of iron (II) sulphate and potassium bitartrate. No clear difference was observed between the natural and chemical mordants.

Dyes belong to an important class of pollutants that can be identified by the human eye¹⁶. In this study, the colors of the dyebath effluents were determined with SAC values which were presented in Table 2. Samples have been diluted with the rate of 1/50 for the measurement.

Mordant Name	Wavelength*		
	436 nm	525 nm	620 nm
Without Mordant	0.2231	0.078819	0.04601
Potassium bitartrate	0.16156	0.034106	0.01528
Iron (II) sulphate	0.24788	0.10988	0.086546
Black Tea	0.2204	0.081619	0.045397
Oak wood ash	0.26998	0.15039	0.08556

* Samples dilution rate: 1/50

Table 2: The color values of dyebath effluents*

The lowest and the highest colors were obtained from the dyebath effluents of dyeings with potassium bitartrate and oak wood ash mordants, respectively. The color of dyebath effluent of dyeing with black tea mordant and that of without mordant (as control) exhibits similar color values.

The pH, SS and EC values of dyebath effluents are shown in Table 3. pH of the iron (II) sulphate and potassium bitartrate are in acidic character. The others are in alkaline character or close to neutral character.

Mordant Name	pH	SS (mg/L)	EC (μ S/cm)
Without Mordant	6,62	734	2530
Potassium bitartrate	5,18	586	2940
Iron (II) sulphate	3,72	849	3130
Black Tea	6,05	653	2490
Oak wood ash	8,3	642	2900

Table 3: The pH, SS and EC values of dyebath effluents.

It is also seen in Table 3 that the lowest and the highest EC values were obtained from the dyebath effluents of dyeings with black tea and iron(II) sulphate, respectively.

3.2 Color Properties of Dyed Samples

Color properties were measured by Datacolor 600 spectrophotometer. Colorimetric data of dyed samples are shown in Table 4 and Figures 1-2.

Mordant	$f(k)$	L^*	a^*	b^*	C^*	h°
Without Mordant	12.0	65.20	11.30	19.86	22.85	60.35
Potassium Bitartrate	31.6	63.55	16.08	31.89	35.71	63.24
Iron (II) Sulphate	10.9	59.63	4.99	9.08	10.37	61.20
Oak Wood Ash	23.5	66.82	24.62	5.93	25.32	13.55
Black Tea	11.7	67.09	24.20	14.03	27.98	30.10

Table 4: CIELAB Colorimetric data of dyed samples

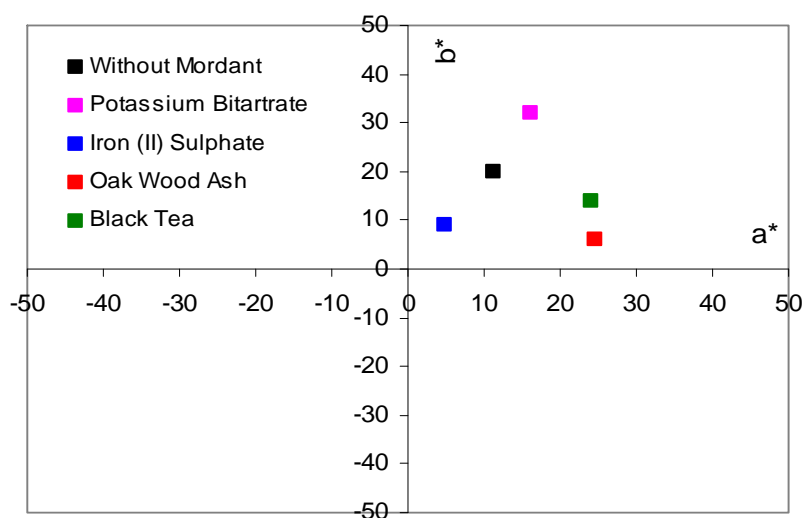


Figure 1: a^* - b^* plot.

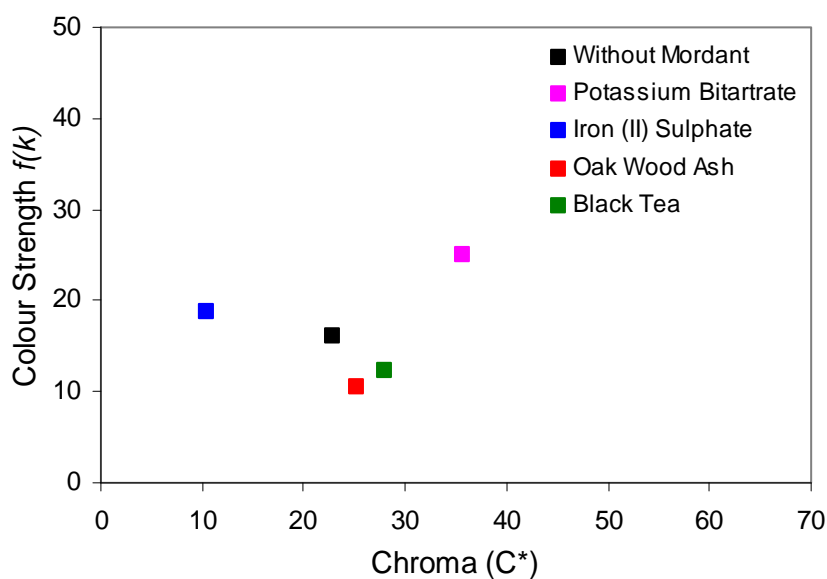


Figure 2: Color strength versus chroma

Color yield ($f(k)$ value) of control dyeing (without mordant) is 12.0. The dyeing with black tea and iron (II) sulphate mordants exhibit lower color strength by 11.7 and 10.9, respectively. The highest $f(k)$ value (31.6) and highest chroma (35.71) were obtained by potassium bitartrate mordant usage. These results are in parallel with the COD (11906), TOC (2082) values and the effluent colors (Table 2). In the dyeing with potassium bitartrate mordant, it seems that more natural anthraquinones were exhausted by the polyester fabric leading to less dye stuff load in the effluent. Therefore, the lowest COD, TOC, and color values were obtained with potassium bitartrate dyeing.

4. CONCLUSIONS

One may think that natural mordant usage is a more ecological way for natural dyeing in comparison with chemical mordant. However, in this research, the best results for environment (with lower COD and TOC values) and the highest color strength value (with higher $f(k)$ value) were obtained by a chemical mordant which is potassium bitartrate mordant.

As discharge standards are becoming more stringent, the conventional chemical (coagulation-flocculation) and biological (activated sludge, sequential bed reactors, anaerobic/anoxic) processes are widely used for the treatments of dyebath effluents, however, with a rather limited success. Therefore, these effluents often require the pre-treatment of segregated process streams (e.g. dyebath effluent) using alternative, advanced oxidation processes (AOPs) that have more recently been used to treat refractory and/or toxic pollutants

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SEWING PROCESS OPTIMIZATION BY THE ANALYSIS OF THE STRUCTURE OF TECHNOLOGICAL OPERATION

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Keywords: work structure, decomposition of work operation, technological process, optimization

Abstract: *Decomposition of work operation leads to the structure of technological processes. It is necessary to comprehend the structures of technological processes in garment production in order to optimize production process and improve productivity. By dividing work operations into technological processes it is possible to analyze each individual process. This is the basis for better and improved work method. The structure of technological processes depends on the type of garment product, type and technical equipment of sewing machines, work methods and work places. This paper deals with the influence of two work methods. It was carried out through the analysis of the structure of technological operation of sewing hems on women's T-shirt based on the influence of parameters determining the final structure of an individual technological operation. On the basis of this analysis, it can be noticed that using sewing machines causes less technological processes and time needed for their conduction, which leads to shorter time of technological operation of sewing (time is shorter for 0,600 min (66,7%).*

1. INTRODUCTION

One of the main characteristics of industrial production is that the work is divided into smaller work stages, technological work operations, technological processes, i.e. grips and movements. Depending on seam type, shape and length of seam contour, the position of article sheets as well as on type and technical equipment of sewing machine, technological process of garment sewing puts together different technological operations of sewing that are different in number, type and time needed for conducting technological processes. The whole operation process includes many movements. Thus, it is necessary to divide those operations into technological processes, registered movements in order to enable analytical approach to many technical and technological parameters. This would rationalize the production process itself.

2. TYPES OF TECHNOLOGICAL PROCESSES

There are two categories of technological processes in the cycle of processing technological work operation: basic technological processes needed for changing on the working object and accessory technological processes enabling conducting this change. A technological sewing operation may include more than one identical technological processes.

According to its structure, technological operation of garment sewing can include following technological processes^{1,2}:

- Mechanical technological procedures (**m**): procedures for changing on the work object carried out by sewing machine.
- Mech Manual technological procedures (**mm**): procedures in which both machine and worker carry out the change on the work object. These procedures include all sewing operations on universal sewing machines in which the worker holds and leads work project while the sewing machine conducts sewing process.
- Manual technological process (**M**): these procedures include changes on work object carried out by worker himself.
- Accessory machinery technological processes (**am**): procedures that contribute to the conduction of work. These procedures do not include any changes on work object.
- Accessory Mech Manual technological processes (**amm**): when the production process is stopped, the worker carries out preparatory grips i.e. adjusts the next segment of object contours while the machine holds the object with the needle and the pedal (the object is not moving).
- Accessory manual technological processes (**amt**): these procedures are carried out prior to machinery, Mech Manual and manual processes. They are carried out by the worker. They include preparation of work object as an input and storage of the work object as output size after the working process has been done.
- Hidden manual technological processes (**hm**): these procedures occur as a consequence of production automation. They are partially or completely carried out with the working process of the machine and they are independent of the machine.

Figure 1 shows the structure of technological processes according to the category of performance.

The mark of the structure of technological process						
m						
mm						
M						
am						
amm						
amt						
hm						
	1	2	3	(5)	4	6
Time of technological process						

Figure 2: structure of technological processes according to the category of performance

2.1 Timing of technological processes

Technological processes depend on time. Thus, testing of the structure should include the time needed for carrying out the processes. Time needed for carrying out some work is defined by work method. Technological processes are carried out within the basic time.

Additional times do not affect object changing during the working process.

Additional times are affected by the organization of working process itself because good organization may lead to time saving operations. Timing technological processes requires precise instruments for registration of working time.

According to the structure of technological processes, within the technological work operation, conduction times may be as follows^{1,2}:

- Time of machinery technological procedure t_m
- Time of Mech Manual technological procedure t_{mm}
- Time of manual technological procedure t_M
- Time of accessory machinery technological procedure t_{am}
- Time of accessory Mech Manual technological procedure t_{amm}
- Time of accessory manual technological procedure t_{amt}
- Time of hidden manual technological procedure t_{hm}

Different technological procedures with their times can be seen in different sewing operations. Defining time needed for conducting technological procedures can be done by appropriate mathematical expressions. Technological operation of sewing includes different basic and accessory technological procedures. That is why the time of technological operation of sewing (t_{op}) is expressed as the sum of technological and accessory times^{2,3}.

$$t_{op} = \Sigma t_t + \Sigma t_p \quad (1)$$

Where: t_{op} - Time of technological operation of sewing (s),
 t_t - Technological time of technological procedure (s)
 t_p - Accessory time of technological procedure (s)

3. EXPERIMENTAL

This paper deals with the influence of two work methods. It was carried out through the analysis of the structure of technological operation of sewing hems on women's T-shirt. This operation was carried out by the special sewing machine W2600 PEGASUS and automatic sewing machine UNION SPECIAL KS122 K01-2548UT4A CD. Single right hem on the T-shirt was sewed by the stitch type class 600 (covered chain stitch)⁴, sewing length 92cm. Figure 2 shows sewing segments, tables 1 and 2 show the structure of technological procedures and figures 3 and 4 show graphics of technological procedures for analysed work operations.

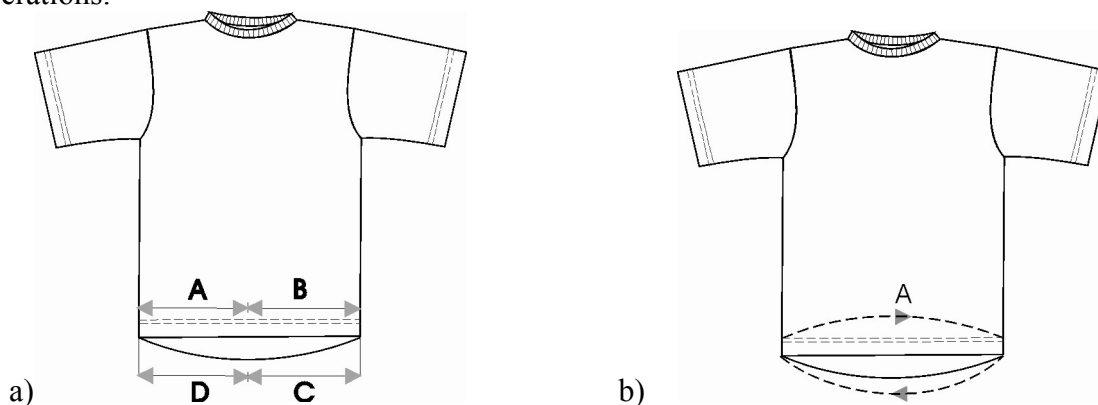


Figure 2. Sewing hem on women's T-shirt a) on speed sewing machine and b) on automatic sewing machine.

The sewing process on a special sewing machine is carried out in A, B, C and D segments. This operation is divided into 10 technological procedures. The structure of these

procedures is shown in table 1. Average time values for each technological procedure were calculated on the basis of conducted measurements of described technological procedures.

Number of technological procedure	Description of technological procedure	Mark of the structure of technological procedure	Mark of the time of technological procedure	Average basic time of technological procedure (sec)
1	manual taking of the T-shirt and putting it on the working plate of the machine	Amt	t _{amt}	4,68
2	manual adjusting of hems and putting under the pedal	amt	t _{amt}	6,15
3	Mech - Manual sewing of segment A's hem	mm	t _{mm}	5,39
4	First sewing stoppage and mach-manual adjusting of hems	amm	t _{amm}	5,45
5	Mech - Manual sewing of segment B's hem	mm	t _{mm} *continue Table	5,51
6	The second sewing stoppage and Mech - Manual adjusting of hems	amm	t _{amm}	5,41
7	Mech - Manual sewing of segment C's hem	mm	t _{mm}	5,32
8	The third sewing stoppage and Mech -manual adjusting of hem	amm	t _{amm}	5,39
9	Mech - Manual sewing of segment D's hem	mm	t _{mm}	5,40
10	Sewing stoppage and manual storage of the article sheet	amt	t _{amt}	5,30
Total				54
$t_{op} = \sum t_{mm} + \sum t_{amm} + \sum t_{amt}$				

Table 1. The structure of technological procedures of sewing hems on T-shirt carried out on the special sewing machine.

Graphics of the structure of technological procedures according to the values of average times, which is shown in table 1, is given in the figure 3.

Mark of the structure of technological procedure										
mm										
pmr										
pr										
	1	2	3	4	5	6	7	8	9	10
Time of technological procedure	t_{amt}	t_{amrr}	t_{mm}	t_{amr}	t_{mm}	t_{amr}	t_{mm}	t_{pmr}	t_{mm}	t_{amtr}

Figure 3. Graphics of the structure of technological procedures for sewing hems on special sewing machine according to table 1.

Sewing process conducted on automatic sewing machine is carried out in one segment A. This operation is divided into 4 technological procedures. Technological procedure number 1 is hidden accessory and is carried out simultaneously with the automatic sewing machine. The structure of these procedures is shown in table 2.

number of technological procedure	description of technological procedure	number of the structure of technological operation	number of the time of technological procedure	average basic time of technological procedure (sec)
(1)	manual taking of the T-shirt and putting it on the working plate of the machine	hm	t_{hm}	(3,32)
2	manual adjusting of hems and putting under the pedal	amt	t_{amt}	5,70
3	mechanical sewing of segment A's hems	m	t_m	7,33
4	Sewing stoppage and manual storage of article sheet	amt	t_{amt}	4,97
Total	$t_{op} = t_m + \sum t_{amt}$			18

Table 2. Structure of technological procedures of sewing hems on T-shirt in automatic sewing machine

On the basis of calculated average time values for conducting technological procedures that are shown in table 2, figure 4 shows graphics for the structure of technological procedures of sewing hems on automatic sewing machine.

Number of technological procedure structure			
m			
pr			
hm			
	2	(1) 3	4
Time of technological procedure	t_{amt}	$(t_{hm}) t_m$	t_{amt}

Figure 4. Graphics for structure of technological procedures for sewing hems on automatic sewing machine according to table 2.

By analysing the structure of technological procedures of sewing hems (tables 1 and 2), it can be noticed that the better performance of this operation was seen at automatic sewing machine in the way of number of technological procedures (special sewing machine includes 10 while automatic sewing machine includes only 4 technological procedures).

On the basis of testing of the technological procedures structure and on the basis of the analysis, it can be noticed that the structure is affected first of all by leading work object during the sewing process, preparation of the object (taking, carrying, adjusting and putting it under the pedal), and finally by handling the object between sewing and storage procedures.

The level of sewing machine usability is much higher (40% of total time needed for operation). Technical equipment of automatic sewing machine enables switching off accessory mach-manual grips and appearance of hidden manual technological procedures which are conducted simultaneously with machinery technological procedures. This leads to the fact that less time is needed for the whole operation. Introducing automatic sewing machines in production process leads to shorter production time (up to 66%), improved productivity, space and energy saving and high quality products.

4. CONCLUSION

The analysis of technological procedures of work operation enables finding better solutions in the area of work methods, applied means of work, new technology in order to optimize sewing of garment products. Therefore, this paper shows an example of defining structure of technological procedure for sewing hems on women's T-shirt using two means of work with different construction. This analysis shows that automatic sewing machine has much better performances comparing to special sewing machine. The main difference between these two machines can be seen in the number of technological procedures and time needed for conducting the operation (time is shorter at about 66,7%).

Given results approve the importance of defining optimal work method as well as its influence on the structure of technological procedure of sewing and the time needed for conducting the operation.

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Body conformations for the Romanian female population and specific fashion proposal

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Abstract: *The clothing products are characterized by a wide variety of figures and sizes depending on the body shape and sizes, product type and the properties of the materials they are made of. Using the anthropometric database, statistical processings regarding the differences between the main body girths in order to highlight the classification of female subjects in various shape categories, in this case geometric shapes were developed. For each group, graphic proposals of clothing products are presented in accordance with the fashion trends for the season autumn-winter 2011/2012.*

Key words: shape category, design, female population, clothing

Introduction

In the manufacture process of clothing in the customised/individual system, the pattern designer and the user connection is most often direct and the designer can measure directly on the body those anthropometric dimensions relevant to the type of product and absolutely necessary for the model design. To develop a custom-made garment, the initial information about the body are obtained directly by measuring the customer, utilizing a number of anthropometric indicators established by the pattern designer according to the type and the model of product [1].

An advantage of our days is the advanced technology in the field of body measurements through three-dimensional scanner. Three-dimensional body scanning allows garment manufacturers in the industry to change their vision of the clothing production from large series to unique garments that have aesthetic aspects specified by the client and individual sizes. A multitude of advanced technologies, including 3D scanning, have developed an explosive phenomenon of “mass customization”, introducing clients in the process of creation and designing the model, resulting “made-to-measure” articles with a high degree of fitting, at competitive prices and with a reduced time of manufacture.

Shape group identification

The clothing products are characterized by a wide variety of shapes and sizes, dependent on the conformation and body sizes, on the product type (destination and decorative features of the product) and the properties of the materials from which are manufactured.

The shape of the product represents the spatial configuration of the product dressing the body of the end-user. Basically, the three-dimensional shape of the garment must be related the human body shape, because the shape of the product is not an exact copy of the human body shape. The degree of similarity between the shape of the garment and the body

shape depends on the position of the product towards the body – the order of the outfit layers and the support area on the body - model features, age and conformation of the end-user [2].

The shape of clothing is related to human body and can be analyzed only with its appearance, proportions and movement. The unity between garment form and content express itself through the connection between shape and destination of the product (for whom and for what was created that garment). To reproduce a garment form is necessary to determinate a shape which tends to the shape of the garment, correlated with the body shape.

Using the database resulted from the anthropometric survey done by National Research and Development Institute for Textiles and Leather in 2008, statistical processing was made regarding the differences between the main body circumferences, whatever the height and weight of the person was, to highlight the classification of female subjects in different conformational groups, in this case geometric shapes [3].

The female body became an example, the woman being usually the main exponent of fashion. As selection criteria were used the differences between:

- bust circumference and hip circumference;
- bust circumference and waist circumference;
- waist circumference and hip circumference.

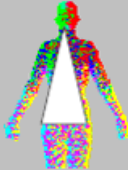

Individual shape category information and clothing recommendations


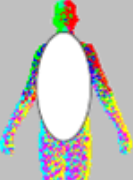
When descriptions of different body or shape category are discussed, the terms “endomorph, mesomorph and ectomorph” are not usually the most common but terms like “apple, pear, triangle, oval” are used most often. So figure types are categorized by name of shapes, letters/numbers and fruits/vegetable like:

- ❖ apple and pear are identifiers in the fruits/vegetable category
- ❖ oval, circle, round, hourglass, rectangle, straight, ruler, triangle, inverted triangle, cone belong to shape category;
- ❖ “O”, “X”, “H”, “A”, “8” belong to letters/numbers category.

Table no 1 characterizes these figure types. This paper describes the geometric forms of the human body and clothing according to shape categories using scanned image with the females that exemplify each geometric shape. For each shape category are presented graphical proposals for clothes according to the fashion trends for autumn-winter 2011/2012 season. Clothing recommendations in the form of graphics highlight in terms of style, each body form.

Table 1. Common shape grouping

Figure Type	Traits	Illustration
Triangle “A” Frame Pear Spoon	<ul style="list-style-type: none"> - Shoulders narrower than hip - Bottom heavy with weight mainly in buttocks, low hips and thighs - Bust is small to medium - Upper body smaller than lower body 	
Hourglass Figure “8” “X” Frame	<ul style="list-style-type: none"> - Equally broad on top and hips - Thin at the waist, usually 25 or more centimeters smaller than chest and hips 	

Rectangle Ruler "H" Frame	<ul style="list-style-type: none"> - No definition at the waistline - Shoulders and hip about the same width - Equal body proportions 	
Oval Circle/Round Apple Diamond "O" Frame	<ul style="list-style-type: none"> - Top and bottom are narrow - Chest and belly are where weight is found - Skinny legs 	

The shape category of **Triangle** utilizes the underlying criteria that the hip circumference is larger than the bust circumference and the ratio hip circumference/waist circumference is small. The person with a Triangle shape has the appearance of being larger in the hips than the bust without having a defined waistline (figures no 1 and 2). This shape is the most common one, but feminine because women are defined by having the shoulders wider than the hips.

Women within the Triangle shape category are advised to wear simple trousers, slightly flared skirts or bell form hiding the more rounded sides, jackets with big lapels, blouses with ruffles, strapless dresses - "Empire", drawstring waist coats, marking the waist belts (figure no 3). In addition, the vertical stripes or seams on the lower body camouflages the area, and light colors, design accents or decorative applications on the upper body distract attention from the hips.

The **Hourglass** shape is defined by the underlying criteria that if a subject has a very small difference in the comparison of the circumferences of the bust and hips and if the ratios bust circumference/waist circumference and hip circumference/waist circumference are about equal and significant, then the shape will be in the Hourglass category. The person with an hourglass shape has the appearance of being proportional in the bust and hips with a defined waistline. Figures no 4 and 5 present examples of bodies with this ideal shape.



Figure no 1. Triangle shape category

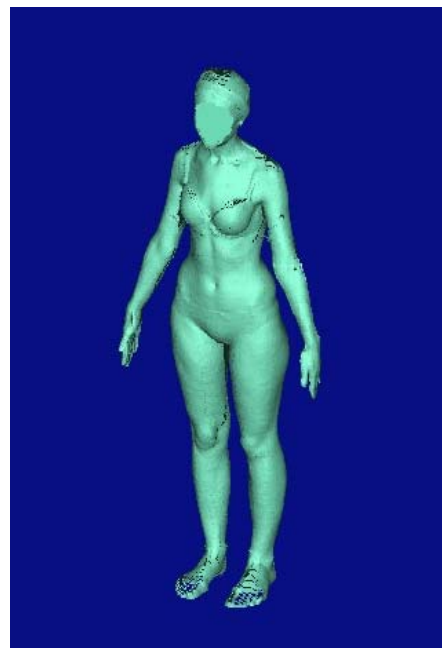


Figure no 2. Subject from Triangle shape category



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Figure no 3. Outfit proposals for females within the Triangle shape category

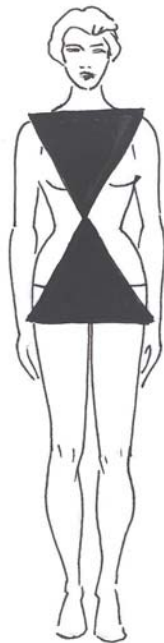


Figure no 4. Hourglass shape category

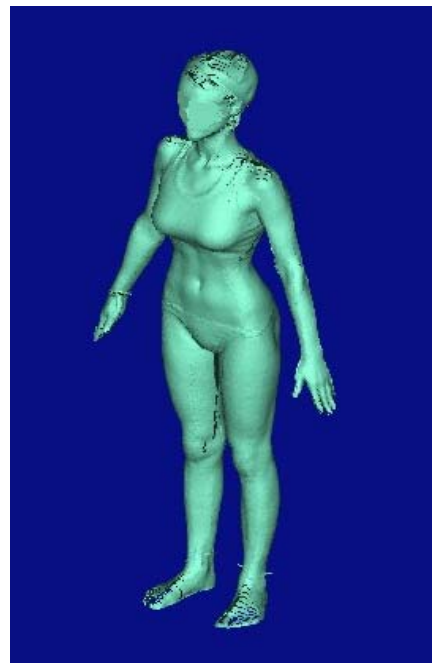


Figure no 5. Subject from Hourglass shape category

Women with the Hourglass body shape are advised to wear outfits that fall gently flowing the body, semi-molded and molded clothes, shirts with deep V-or U décolletages, dresses that accentuate the waist, straight trousers, tapered, flared or slightly flared skirts, sweaters with high collar (figure no 6).



Figure no 6. Outfit proposals for females within the Hourglass shape category

The **Rectangle** category has the underlying premise that bust and hip measure are fairly equal and the ratios bust circumference/waist circumference and hip circumference/waist circumference are low. The person with a Rectangle shape is characterized by not having a clearly discernible waistline. Therefore, the bust, waist and hips are more inline with each other (figures no 7 and 8).

Women who are in the Rectangle shape category should wear semi-molded clothes with short sleeve or sleeveless if arms are thin, with normal or small décolletages, overlapped knitted dresses that veil the body and creates an ideal hourglass form, with furbelows on the top, A – form blouses, wide at the bottom, straight trousers and slightly flared, pleated (figure no 9).

The **Oval** shape category is defined by utilizing the body measurements of the bust, waist, hips and abdomen. The person with an Oval shape is characterized by having several rolls of flesh in the midsection of the body and appears to have a large midsection in comparison to the rest of their body. The shape from the front view can be different for each subject but the side view is where the true characteristics of the Oval shape are seen (figures no 10 and 11). The oval shape category utilizes the underlying criteria that the average of the subject's waist and abdomen measures is less than the bust measure.

Women within the Oval shape category are advised to generally wear easily loose clothes, shirt and pants in the same color, deep décolletages, straight or slightly flared skirts, pants too, earrings, chains, to attract attention in the upper part of the body (figure no 12).

In order to ensure the equilibrium between the clothing and the body and the aesthetic requirements must be achieved a high dimensional body – clothing correspondence, which is one of the fundamental problems of clothing design. Therefore pattern designers need information about end-users and clothing, information that is obtained through a constant research on morphological indicators characterizing the exterior shape of the body.



Figure no 7. Rectangle shape category

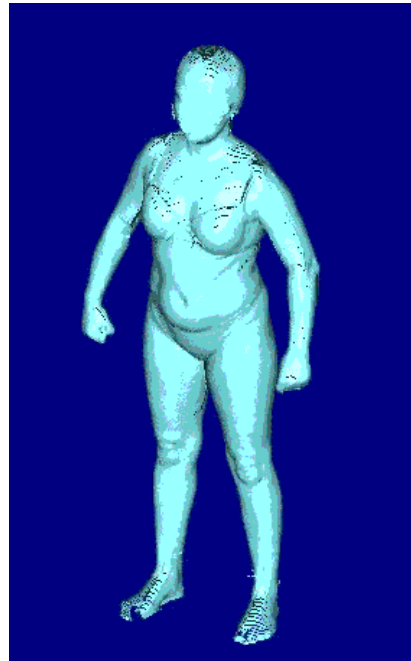


Figure no 8. Subject from Rectangle shape category



Certex

Figure no 9. Outfit proposals for females within the Rectangle shape category



Figure no 10. Oval shape category

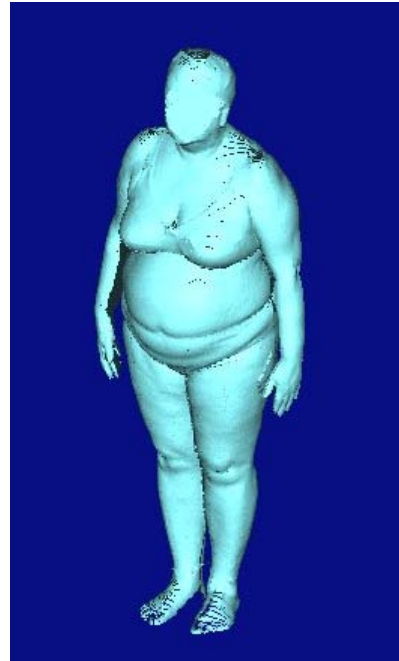


Figure no 11. Subject from Oval shape category



Certex

Figure no 12. Outfit proposals for females within the Oval shape category

Conclusions

Depending on the body shape category of each end-user, outfit graphics proposals can be developed in accordance with fashion trends in terms of style that highlight each body form.

Acknowledgements

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RESEARCHES ON MACROMOLECULAR AND POLYMERIC COMPOUNDS FOR HOST-GUEST CHEMISTRY

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Abstract: *The paper presents the researches regarding obtaining/use of supramolecular/polymeric compounds in decontamination techniques for textile industry. Use of these macrocyclic compounds which have nanofiltration properties represents a possibility that could be developed in order to respond to specific demands of ecological aspects from the textile chemical processes. The process is simple and lead to very good results.*

1. INTRODUCTION

Ion exchange resins are isoporous structures based on polystyrene cross-linked with divinylbenzene, sorption taking place through an ion exchange mechanism immobilizing the dye of anionite through a sulfonic group. Ion exchange resins are substances that are able to hold ions in a polyelectrolyte solution and are essentially composed of an inactive matrix on which ion exchange active groups are grafted. Both domestically and internationally are used ion exchange resins that have a gel structure, macropores or hyper-crosslinking. Gel-type structure resins are obtained by suspension copolymerization of a substance that forms the polymer network [styrene, acrylic acid and its derivatives] with a cross-linking agent such as divinyl-benzene and sometimes formaldehyde. These resins in swollen state contain micro and mesopores, which sizes depend on the amount of divinyl-benzene (DVB) and the degree of swelling.

The resins used in this paper were obtained with the same raw materials but with a modified technique of copolymerization in the presence of pore generator and a larger amount of divinyl-benzene (DVB);

Calixarenes are supramolecular compounds, characterised by a three-dimensional shape and, as structure, by a wide upper rim and a narrow lower rim and a central annulus. With phenol as a starting material the 4 hydroxyl groups are intra-annular on the lower rim. Calixarenes exist in different chemical conformations because rotation around the methylene bridge is not difficult.

Calixarenes are cyclic oligomers formed by condensation of phenols and formaldehyde, and some calixarene derivatives can be obtained by substitution reactions after the condensation reaction.

The condensation of monohydroxyl phenols with formaldehyde, in acid catalysis leads to the formation of very small amounts of calixarenes [1,2], which were not isolated. Calix[n]arenes that have been obtained with higher productivity in acid catalysis were: calix[4]resorcinarenes, by condensation of resorcinol with acetaldehyde [3,4], propionaldehyde [3], isobutyraldehyde [5], heptaldehyde [6], dodecylaldehyde [6],

isovaleraldehyde [3], benzaldehyde [3,6]; calix[n]arenes of non-hydroxyl aromatic compounds, by condensation of formaldehyde with: mesitylen and 1,2,3,5-tetramethylbenzene [7], chloromethyl-mesitylen [8], 2,6-dimethyl-4-methoxy-benzyl alcohol [9], 2-methoxyazulene[10].

The paper presents the researches regarding the realization of some technological variants for decontamination of wastewaters from textile, leathers and shoes industries, using of macrocyclic, calixarene compounds, whose performances comply with the Directive 2000/60/EC through: specific measures of progressive reduction of water pollution and disposals, emissions and losses of priority dangerous compounds, promotion of durable use of waters, ensuring the best practices and technologies, regarding the protection of the environment. The techniques of interest used for the solution of wastewaters decontamination include: liquid – liquid extraction, ionic exchange, liquid organic membranes extraction and so on.

According to literature, calixarene and ion exchange type compounds can be used both as sequestrants and as dyes complexants from wastewaters, by an extraction technique.

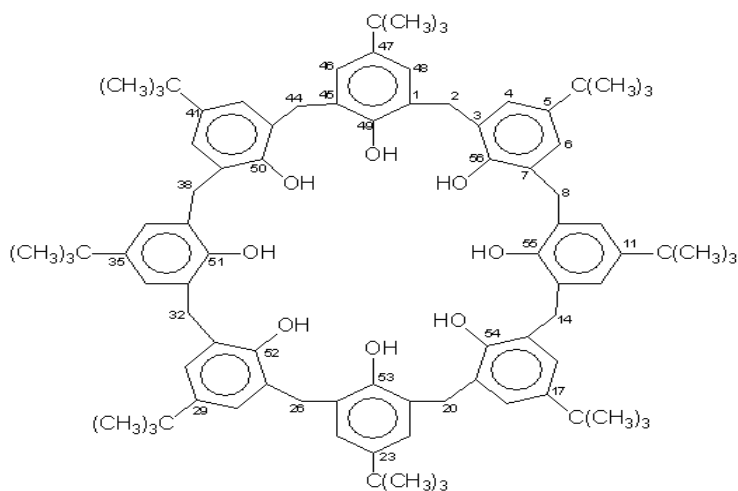
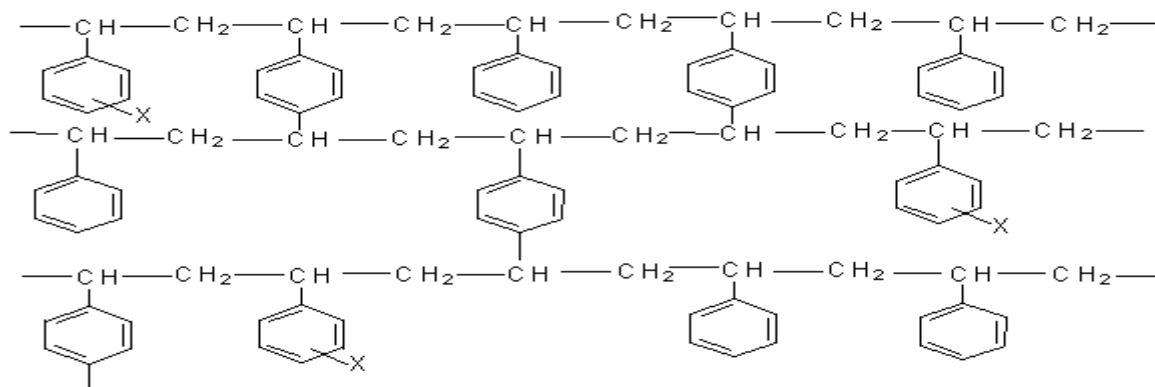


Figure 1. *p*-tert-butylcalix[8]arene or 5,11,17,23,29,35,41,47-octa-*t*-butyl-49,50,51,52,53,54,55,56-octahydroxy-calix[8]arene



X = SO₃H; N(CH₃)₃

Figure 2. Divinyl-benzene resin

2. EXPERIMENTAL PART

The technological process for decontamination of textile wastewaters with calix[8]arene has been previously described [11]. In this paper we shall focus on ion exchange resins.

The resin used is a Purolite™ type from Hypersol-Macronet™ class of ion exchange resins. It has a post-crosslinked styrene-divinylbenzene carcass with methylene bridges and a trimodal porous structure.

The decontamination of wastewaters has been studied on various amounts of resin and the indicators monitored have been also multiple: dye content, turbidity, conductivity, pH, detergents, phosphates, wastewater type and so on.

The process of activation has been performed in a CSTR vessel, at 25°C and a swelling time of 20-24 hours. The ion exchange is performed through addition of the swollen resin over a known amount of wastewater, with monitoring of pH in time, after specific intervals.

Tests for performances in decontamination techniques for wastewaters derived from a painting process

- The tested decontamination technique is based on the properties of these compounds to form inclusion complexes or host – guest type compounds with ions or small neutral organic molecules
- The decontamination technique consisted in the contact of the wastewater with the decontaminant, by strong stirring, at room temperature.
- The wastewaters post-treated with these decontaminant resins were characterized by physical and chemical methods according to the environment and quality standards.

3. RESULTS AND DISCUSSIONS

The swelling (activation) conditions for Purolite MN 500 in CSTR are presented in the table below.

Table 1. Conditions for activation of Purolite MN 500

No.	Resin amount (g)	Volume of deionized water (mL)	Temperature (°C)	Time (hours)	pH of swelling water (units pH)	Volume of decanted swelling water (mL)
1	2	120	25	20	4.2	118
2	4	120	25	20	3.4	115
3	5	120	25	20	3.3	110
4	6	120	25	20	3.2	109
5	8	120	25	20	3.1	105
6	10	120	25	20	3.0	100
7	15	120	25	20	2.8	94
8	2	120	25	24	4.3	117
9	3	120	25	24	4.1	114
10	4	120	25	24	4	110
11	5	120	25	24	4	110
12	6	120	25	24	4	110
13	1	220	25	24	10.5	219

Based on these results we recommend an activation time of 24 hours, i.e. an amount of 4-5 grams at 120 mL water.

Experiments for treatment of wastewaters from painting processes.

The efficiency of decontamination results from comparison between the results obtained in analysis of initial wastewaters and treated wastewaters.

Table 2. Optimum pH in treatment of wastewaters contaminated with *BEZAKTIV Gelb S – BR* and treated with PUROLITE 500

Wastewater type	Wastewater volume (mL)	Swollen resin volume (mL)	Time (min)	Initial pH	Final pH
<i>painting bath</i>	110	15	30	10.54	7.09
<i>rinsing bath</i>	219	2	30	9.94	8.41
<i>soap bath</i>	110	14	30	8	5.46

Table 3. Optimum pH in treatment of wastewaters contaminated with *BEZAKTIV Rot S – 3B 150* and treated with PUROLITE 500

Wastewater type	Wastewater volume (mL)	Swollen resin volume (mL)	Time (min)	Initial pH	Final pH
<i>painting bath</i>	110	15	30	10.52	6.96
<i>rinsing bath</i>	219	2	30	9.97	7.18
<i>soap bath</i>	110	14	30	7.22	5.72

Table 4. Optimum pH in treatment of wastewaters contaminated with *BEZAKTIV Blau S – FR 150* and treated with PUROLITE 500

Wastewater type	Wastewater volume (mL)	Swollen resin volume (mL)	Time (min)	Initial pH	Final pH
<i>painting bath</i>	110	15	30	10.5	7.6
<i>rinsing bath</i>	219	2	30	10.01	7.08
<i>soap bath</i>	110	14	30	7.44	5.72

Results from decontamination of wastewaters from painting processes with resin volumes of 14, 15 and 16 mL are presented in the tables below.

Table 5. Results from decontamination of *Bezaktiv Gelb S – BR* painting bath, using Purolite resin

painting bath	initial	treated (14)	treated (15)	treated (16)
pH	10.54	7.01	7.09	7.12
Turbidity	0.98	0.96	0.94	0.94
Conductivity, $\mu\text{s/cm}$	16782	17853	18200	17198
Fix residue, mg/L	9820	3560	9120	9130
dye	20.72	39	6.82	34.1
detergent	0.11	0.47	0.46	0.46
phosphates	2.98	3.3	3.26	3.27

Table 6. Results from decontamination of *Bezaktiv Rot S - 3B 150* painting bath, using Purolite resin

painting bath	initial	treated (14)	treated (15)	treated (16)
pH	10.52	7.01	6.96	6.97
Turbidity	1.2	1.2	1.2	1.2
Conductivity, $\mu\text{s}/\text{cm}$	20840	16853	15620	15610
Fix residue, mg/L	11260	8560	8090	8095
dye	68	46	1.66	29.6
detergent	0.20	0.20	0.20	0.20
phosphates	3.86	2.0	1.98	1.99

Table 7. Results from decontamination of Bezaktiv Blau S - FR 150 painting bath, using Purolite resin

painting bath	initial	treated (14)	treated (15)	treated (16)
pH	10.5	7.6	7.60	7.61
Turbidity	1.02	0.96	0.96	0.95
Conductivity, $\mu\text{s}/\text{cm}$	18264	12893	12480	12485
Fix residue, mg/L	10562	6560	6540	6541
dye	75	16.8	11.24	12.6
detergent	0.12	0.27	0.26	0.26
phosphates	3.46	4.3	4.28	4.29

Results from decontamination of wastewaters from rinsing processes with 2 mL volume of resin are presented in the tables below.

Table 8. Results from decontamination of Bezaktiv Gelb S - BR rinsing bath, using Purolite resin

rinsing bath	initial	treated
pH	9.94	8.41
Turbidity	1.08	0.98
Conductivity, $\mu\text{s}/\text{cm}$	4862	6728
Fix residue, mg/L	2980	3560
dye	23.4	2.56
detergent	6.22	12.28
phosphates	0.96	1.06

Table 9. Results from decontamination of Bezaktiv Rot S – 3B 150 rinsing bath, using Purolite resin

rinsing bath	initial	treated
pH	9.97	7.18
Turbidity	1.22	1.28
Conductivity, $\mu\text{s}/\text{cm}$	4682	4620
Fix residue, mg/L	12830	2984
dye	11.4	0.3
detergent	10.20	5.24
phosphates	0.98	0.86

Table 10. Results from decontamination of Bezaktiv Blau S – FR 150 rinsing bath, using Purolite resin

rinsing bath	initial	treated
pH	10.01	7.08
Turbidity	1.56	1.08
Conductivity, $\mu\text{s}/\text{cm}$	6542	3860
Fix residue, mg/L	4200	1980
dye	68.7	4.82
detergent	10.20	8.14
phosphates	0.98	1.08

Results from decontamination of wastewaters from soaping processes with resin volumes of 7, 9 and 14 mL are presented in the tables below.

Table 11. Results from decontamination of Bezaktiv Gelb S - BR soap bath, using Purolite resin

soap bath	initial	treated (7)	treated (14)	treated (9)
pH	7.43	5.4	5.46	5.5
Turbidity	1.96	1.96	1.54	1.65
Conductivity, $\mu\text{s}/\text{cm}$	9842	10435	10420	10421
Fix residue, mg/L	5280	5569	5620	5629
dye	22.5	8.56	4.39	6.5
detergent	30.16	0.47	56.24	0.46
phosphates	1.98	2.69	2.56	2.59

Table 12. Results from decontamination of Bezaktiv Rot S – 3B 150 soap bath, using Purolite resin

soap bath	initial	treated (7)	treated (14)	treated (9)
pH	7.22	5.55	5.72	5.7
Turbidity	2.06	1.98	2.08	2.09
Conductivity, $\mu\text{s}/\text{cm}$	12682	9853	9820	9830
Fix residue, mg/L	2628	5105	5086	5095
dye	15.0	7.7	2.30	4.67
detergent	50.24	46.75	46.32	46.33
phosphates	1.26	2.2	2.16	2.15

Table 13. Results from decontamination of Bezaktiv Blau S – FR 150 soap bath, using Purolite resin

	Bezaktiv Blau S - FR 150			
soap bath	initial	treated (7)	treated (14)	treated (9)
pH	7.44	5.65	5.72	5.61
Turbidity	2.98	1.96	1.64	1.75
Conductivity, $\mu\text{s}/\text{cm}$	8462	6893	6420	6485
Fix residue, mg/L	5420	4560	3840	3841
dye	83.9	11.56	3.92	7.03
detergent	46.18	32.27	32.12	32.16
phosphates	2.44	1.3	1.28	1.29

The degree of discoloration has also been tested through UV spectroscopy, which demonstrates that the decontamination efficiency increases with contact time.

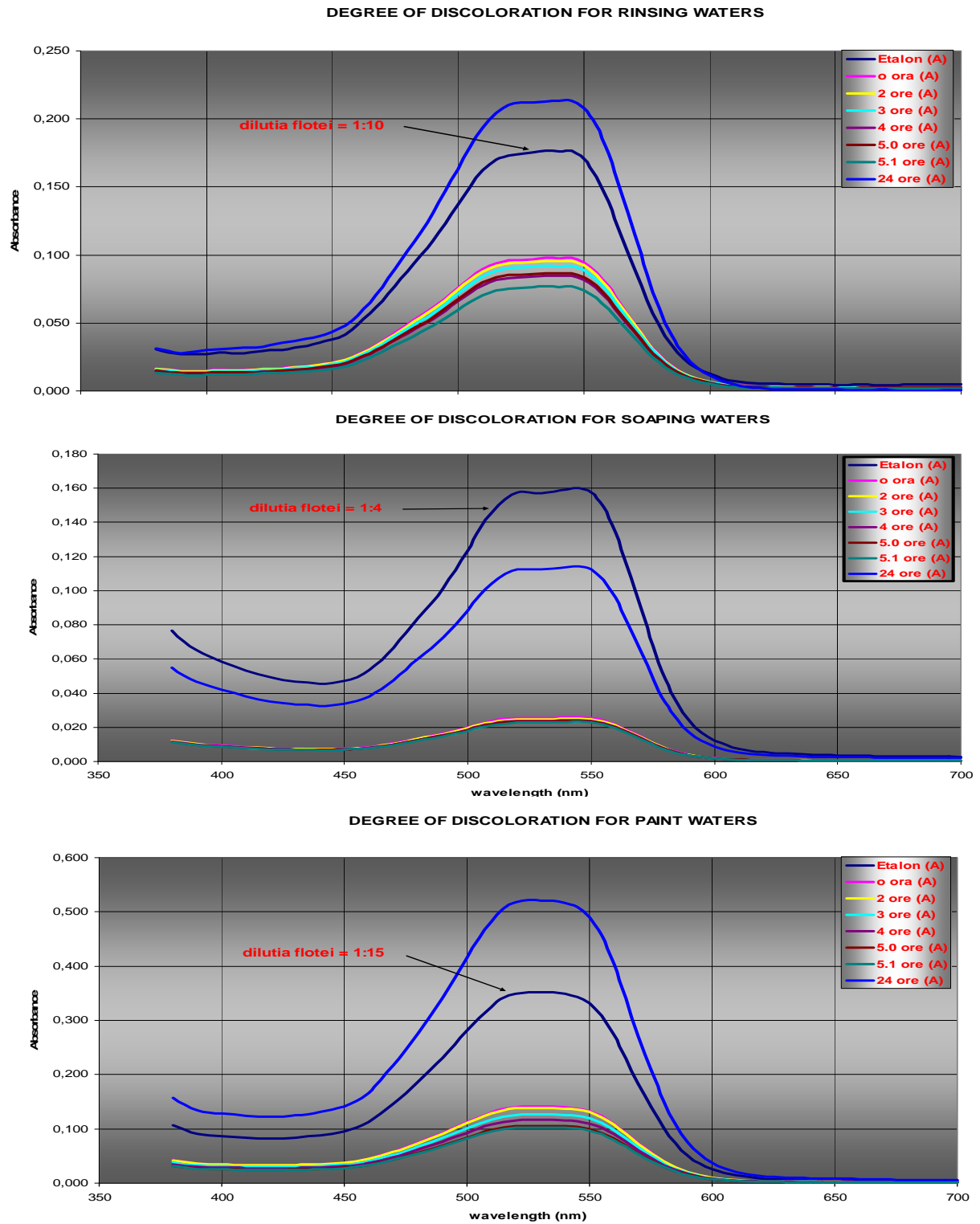


Figure 3. UV spectra at various time intervals for wastewaters treated with Purolite 500

4. CONCLUSIONS

The selected decontamination technique, based on the properties of supramolecular compounds to change or form inclusion complexes of host – guest type with ions or small neutral organic molecules led to good results.

The working phases for this technique are simple and do not present technical difficulties in accomplishment.

The separation of resins from wastewaters can be realized through simple filtration operations.

All the values for the physical and chemical characteristics dropped with the increase of time of contact with the decontaminant.

The promising results obtained in this stage of research make possible the continuation of experiments with other types of resins.

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INFLUENCES OF THE ULTRASONIC DEPOSITION OF METAL OXIDES ON THE PHYSICAL-MECHANICAL PARAMETERS OF TEXTILE PRODUCTS FOR MEDICAL USE

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Keywords: mechanical-physical characteristics, ultrasounds, SEM, medical textiles, zinc oxide, sonochemistry, antimicrobial textiles

Abstract: *Medical textiles represent a large field of the textile industrial world. They have a special, sensitive place because of their scope of improving the life standard in the healthcare units. Because of their various applications they represent a market with a strong impact in the textile “economy”.*

This paper presents some experimental results regarding the effect of an ultrasonic deposition of metallic oxides (zinc oxide) onto their surface on the physical-mechanical characteristics of certain types of textile materials, such as 100% cotton.

The ultrasonic treatment aims at imparting an antimicrobial effect for the textile materials in order to obtain a new class of medical textiles with triple function: health preservation, economic efficiency, and “green” effect.

The results are part of the work financed under the European FP 7 Project – SONO.

1. INTRODUCTION

Antimicrobial textiles continue to raise the interest among scientists and represent a market of important potential with new products emerging every year. A close attention is given also to the technologies used for conferring antimicrobial properties.

Some antimicrobial agents are already conventional such as metals and metal salts, quaternary ammonium compounds, polyhexamethylene biguanides (PHMB), triclosan, chitosan, *N* – halamine compounds, peroxyacids. In addition to these traditional antimicrobials which may come from other industries than the textile industry, such as food industry, different researches reveal the antimicrobial action of compounds like honey and various vegetal products or invertebrate extracts [1].

Probably the most demanding sector of application, in terms of range, quality of the products, and also legal requirements is the medical sector.

This paper presents some experimental results regarding the way the physical and mechanical parameters of textile materials are modulated as an effect of the ultrasonic deposition of zinc oxide nanoparticles.

This work is part of the international project developed in the 7 Framework Program - “A pilot line of antibacterial and antifungal medical textiles based on a sonochemical process” – SONO -, (Grant Agreement no. 228730).

2. METHOD AND MATERIALS

The purpose of the experimentations was the assessment of the efficiency of a new technology of finishing and functionalization by ultrasonation through testing the adherence of the metallic oxide (zinc oxide) nanoparticles onto the surface of the textile materials and analyzing the effect of the functionalization.

For the experimentations there were used textile raw materials (textile fibrous compositions) and nontextile (functionalization products – metallic oxides).

The raw materials were functionalized by a patented method [2] and the installation was working at the Bar Ilan University, Chemistry Department.

The testing of the physical-mechanical and antifungal properties of textile structures before and after the application of the innovative technology was performed at the National Research and Development Institute for Textiles and Leather.

2.1 Textile materials

For the assessment of the efficiency of the metallic oxides deposition process by ultrasonation there were analyzed a series of physical – mechanical and microbiological characteristics related to 2D woven fabrics: 100 % cotton and 100% cotton with ZnO nanoparticles.

The 2D woven fabrics analyzed were fundamental type one, plain namely. The selection of this weave, even though it has as a weak point, with the lower processing yield in comparison with other derivate and combined fundamental weaves, presents as a strong point in the context of this research, the balanced weave on the two threads systems after the number of threads, conferring balanced net square type, this allowing an uniform impregnation in the thickness of the fabric. The plain weave is also a specific weave for bed sheets and personnel protection equipment, robes and pajamas type.

The 2D woven fabrics with plain weave are unbalanced in the 2 threads systems at the technological density, but balanced at the linear density of the threads and at the fibrous composition of the threads.

The textile materials used are considered known textile products, specific to the medical sector final purpose and are provided by the DAVO Star Impex Srl, Romania.

2.2 The ultrasonic treatment

The innovative ultrasonic principle used is the single-step continuous process of the production and at the same time impregnation of the nanoparticles on the textiles surfaces and it is patented at lab scale [2].

The treatment was carried out at BIU on strips of 10 mm wide and the final concentration of zinc oxide nanoparticles, analyzed through ICP was of 1 % ZnO *w/w*.

2.3 Characterization of the textiles

For the characterization of the 2D woven fabrics there are defined the categories in which these final products will be part and in relation to these conceptual categorization the group of characteristics that must be analyzed as a set of quality and performance criteria is established.

2.3.1 Identification of the technical requirements for the tested textile materials

The analyzed textile products are technical textiles and are defined as medical textiles. According to Adanur [3], the technical textiles are specially designed structures that are used in products, processes and services of the non textile industries.

The same author [3] classifies the medical textiles in three main categories:

- a) Textiles for surgery, that contains implantable textiles (surgical thread, vascular graft, materials for cardiac valves etc.) and non implantable textile materials (dressing, bandages, patches);
- b) Textiles from extracorporeal devices (artificial kidney, artificial liver, artificial lung);
- c) Textile products for health care (bed sheets, personal protection equipment, surgical gloves).

Regarding their introduction to market, medical textiles are defined as medical devices and their production is regulated by the European Directive 93/42/EEC [5] with all the specific amendments developed until today.

The 93/42/EEC Directive concerning medical devices defines the notion of medical device as follows:

„medical device means any instrument, apparatus, appliance, software, material or other article, whether used alone or in combination, including the software intended by its manufacturer to be used specifically for diagnostic and/or therapeutic purposes and necessary for its proper application, intended by the manufacturer to be used for human beings for the purpose of:

- *diagnosis, prevention monitoring, treatment or alleviation of disease,*
- *diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,*
- *investigation, replacement or modification of the anatomy or of a physiological process,*
- *control of conception,*

and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means;”

Taking into consideration all these scientific and regulated definitions the final products could be defined as medical, noninvasive with short utilization term textiles.

The technical requirements established for testing the samples took into consideration their categorization as presented above, the standard SR ENV 14237:2003 “Textiles in the health care system”, and the requirement of the end-user, partner Klopman International.

The characteristics for thread and fabric which are essential for revealing the impact of the ultrasonic process on the textile structure and also on the thermal and psycho-sensorial comfort and the efficiency of the nanoparticle adhesion were identified. The analyses were textile and microbiological.

For the samples presented here, 100% cotton and 100% cotton with ZnO the analysed textile characteristics were:

- for fabric: specific mass, technological thickness, density, apparent diameter, breaking force and elongation at break, recovery from creasing, abrasion resistance, slippage resistance at seam;
- for thread: linear density, twist, slippage resistance at seam.

For the microbiological method, the standard SR EN 14119 “Textiles. Resistance to microfungi” was applied.

All the testing methods are in accordance with the international regulations and were realized in a ISO 17025 quality standard accreditation laboratory at the INCDTP.

3. RESULTS

For this paper the characterization for the two types of samples 100 % cotton (Davo) with any treatment and 100 % cotton with ZnO deposition (Davo ZnO) was presented. The

deposition of NP was made on the ultrasonic laboratory equipment as part of the first phase of the optimization of the ultrasonic deposition parameters.

3.1 Mechanical characteristics

In Figures 1-12 the result for the mechanical and physical characterization of the samples cotton 100% and cotton 100% with zinc oxide nanoparticle adhesion is presented.

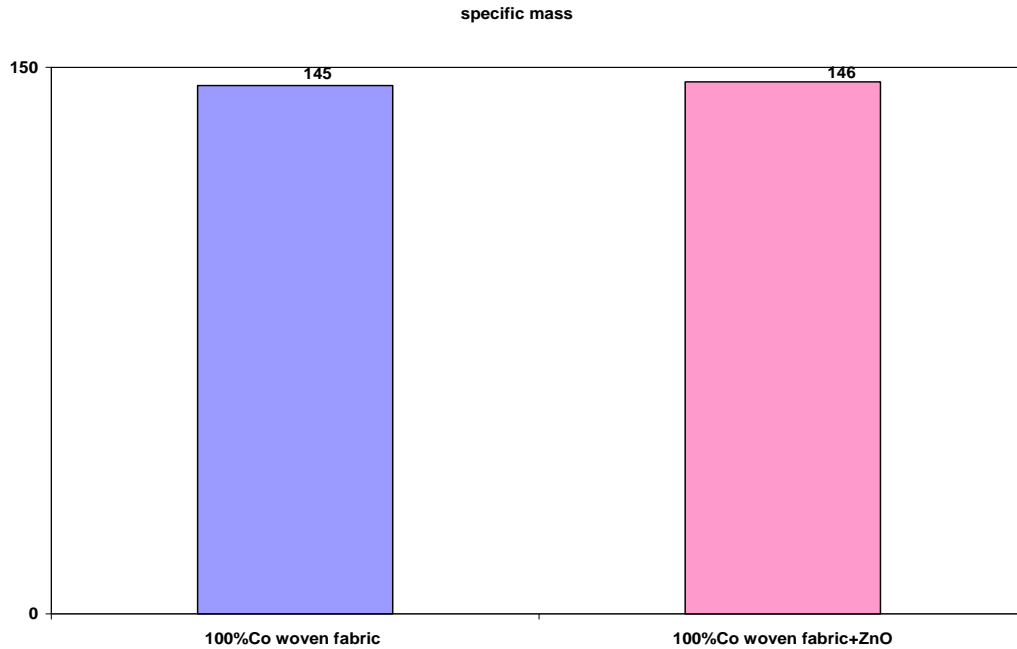


Figure 1. Specific mass (g/m²) for 100% cotton and 100% cotton with ZnO

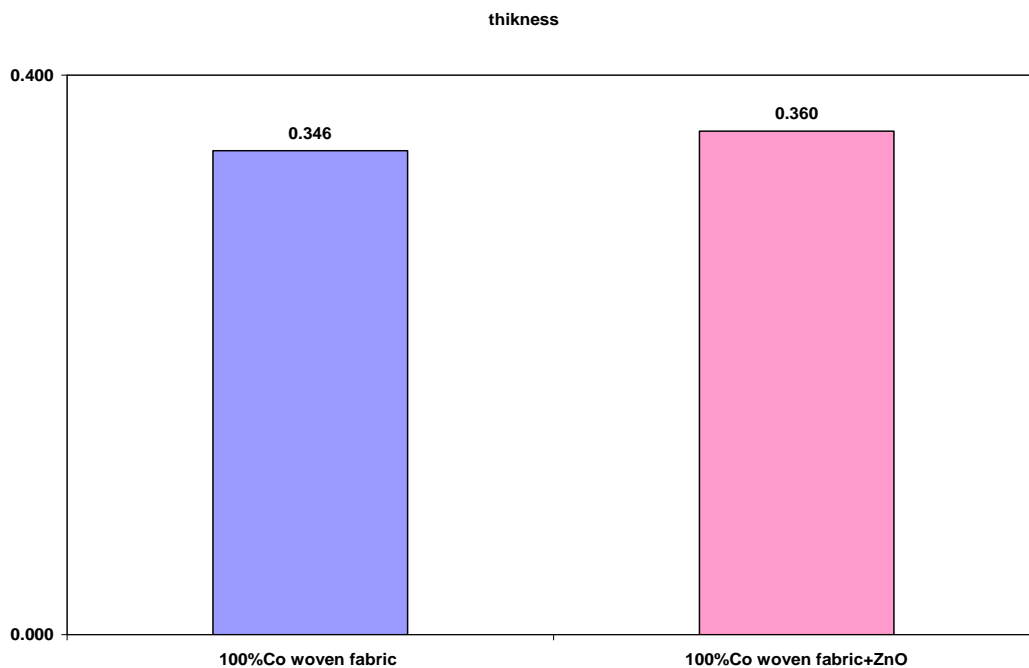


Figure 2. Thickness (mm) for 100% Cotton and 100% Cotton + ZnO

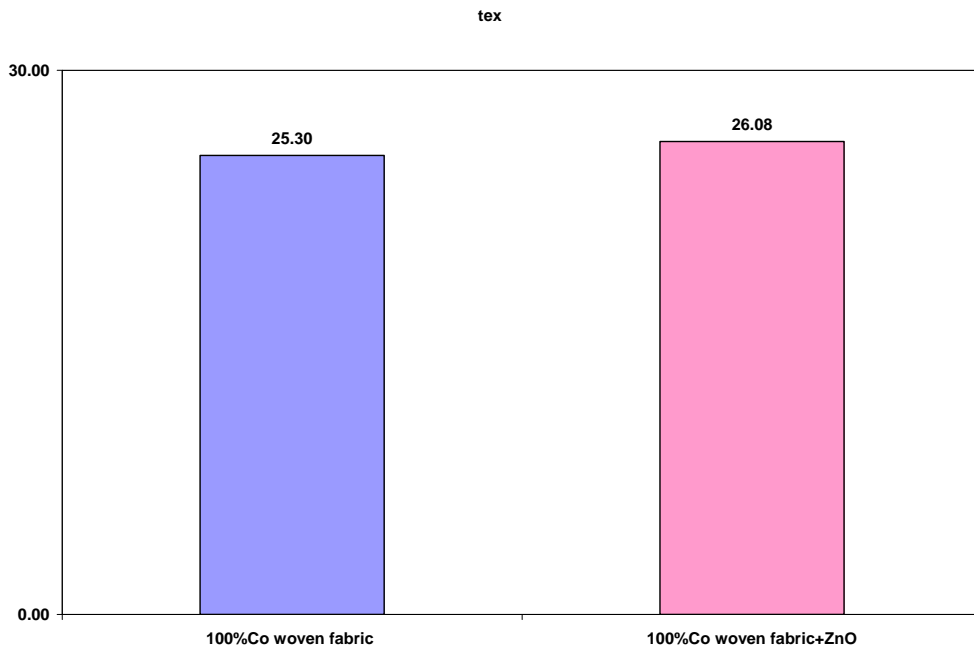


Figure 3. Linear density of thread (Nm) for 100% Cotton and 100% Cotton + ZnO

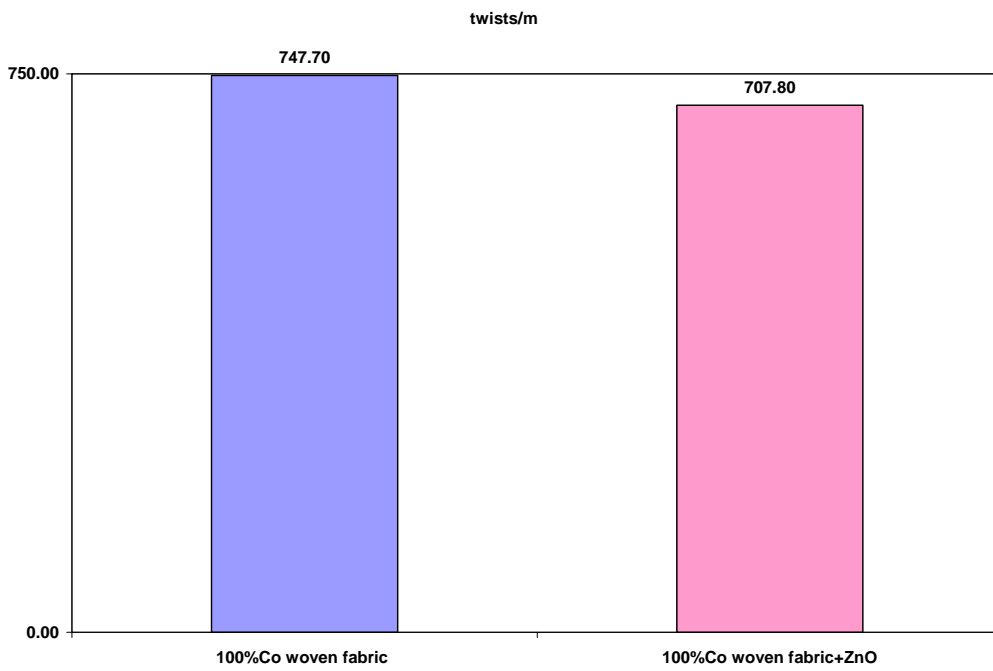


Figure 4. Twist yarn (t/m) for 100% Cotton and 100% Cotton + ZnO

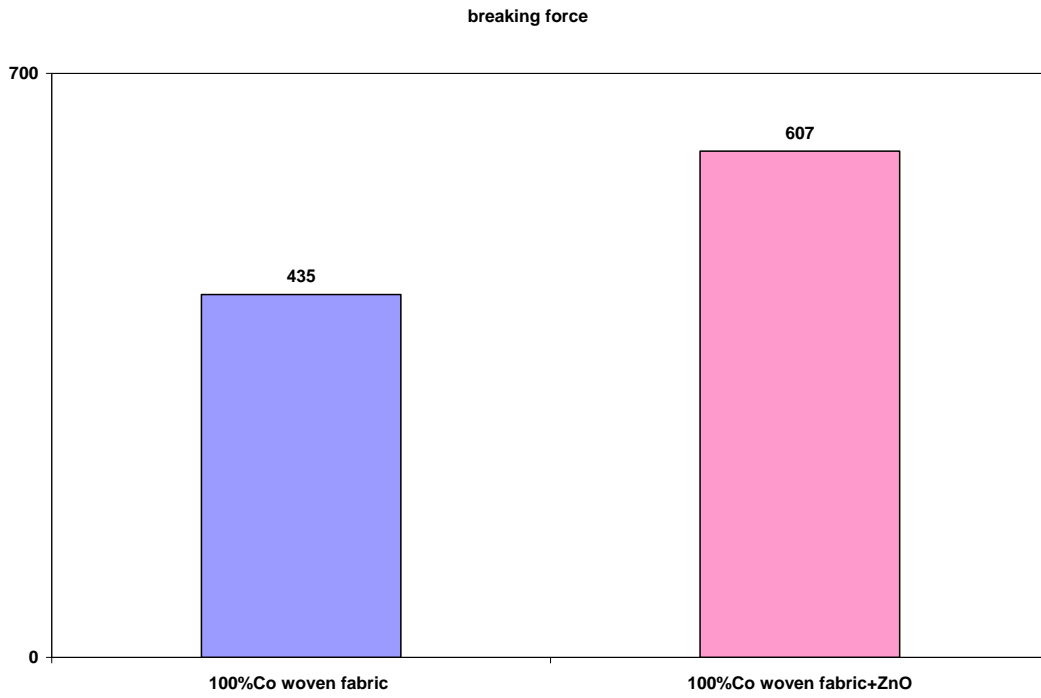


Figure 5. Breaking force (N) for 100% Cotton and 100% Cotton + ZnO

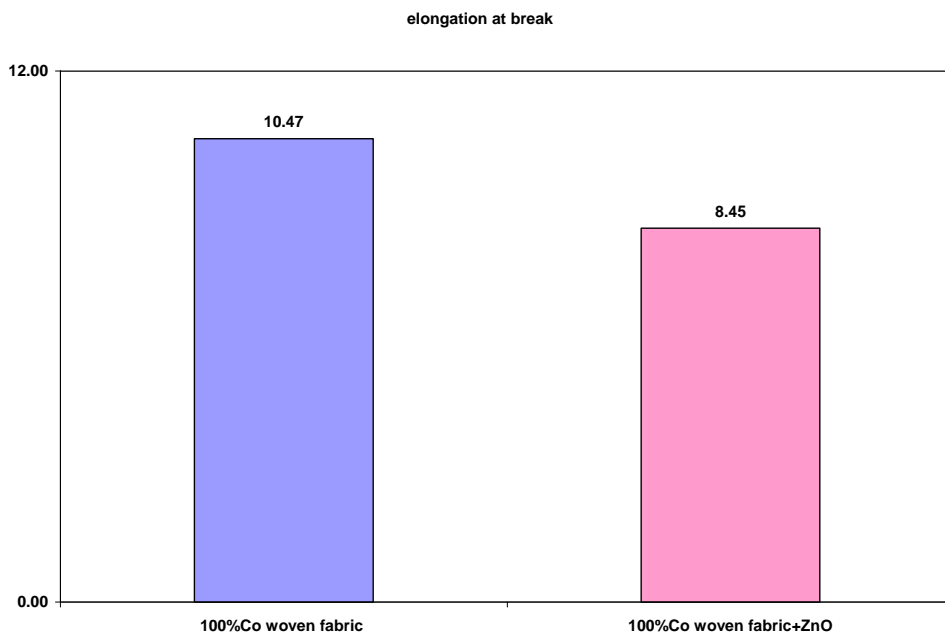


Figure 6. Elongation at break (%; N) for 100% Cotton and 100% Cotton + ZnO

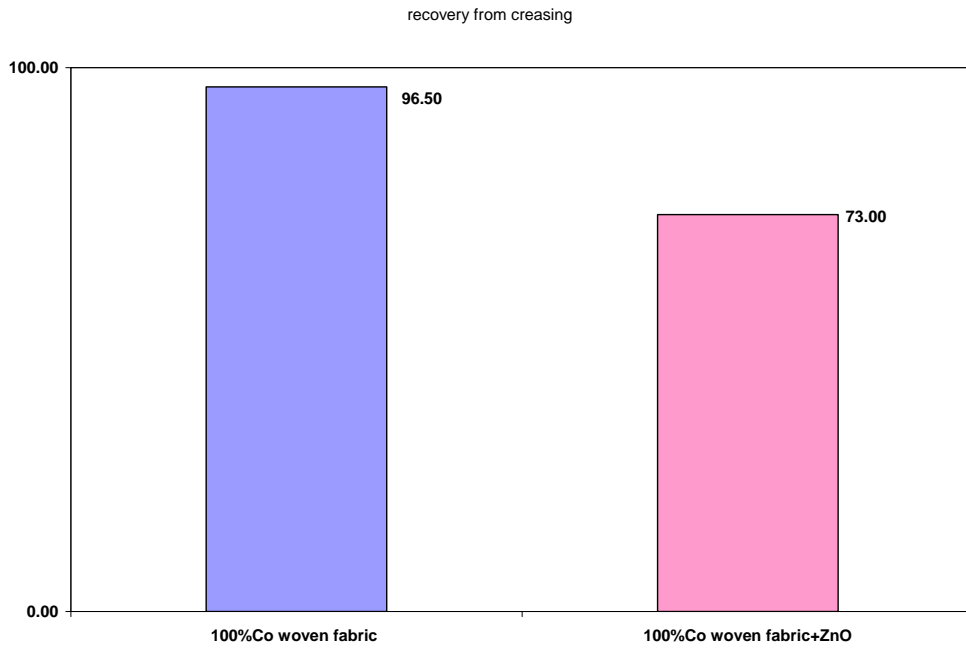


Figure 7. Recovery from creasing (degrees) for 100% Cotton and 100% Cotton + ZnO

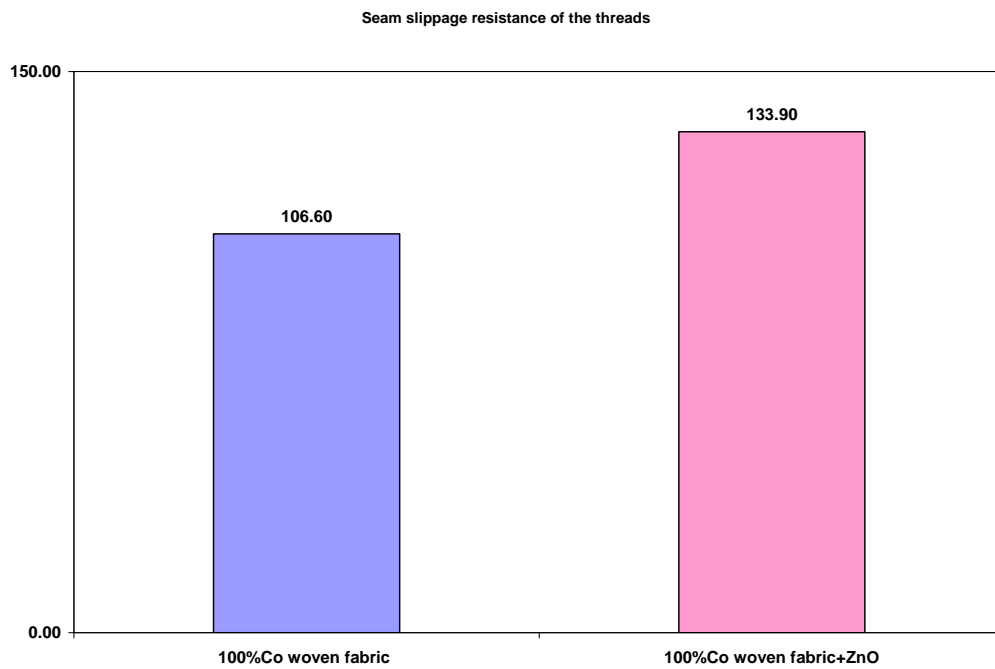


Figure 8. Seam slippage resistance of the threads (N / mm) for 100% Cotton and 100% Cotton + ZnO

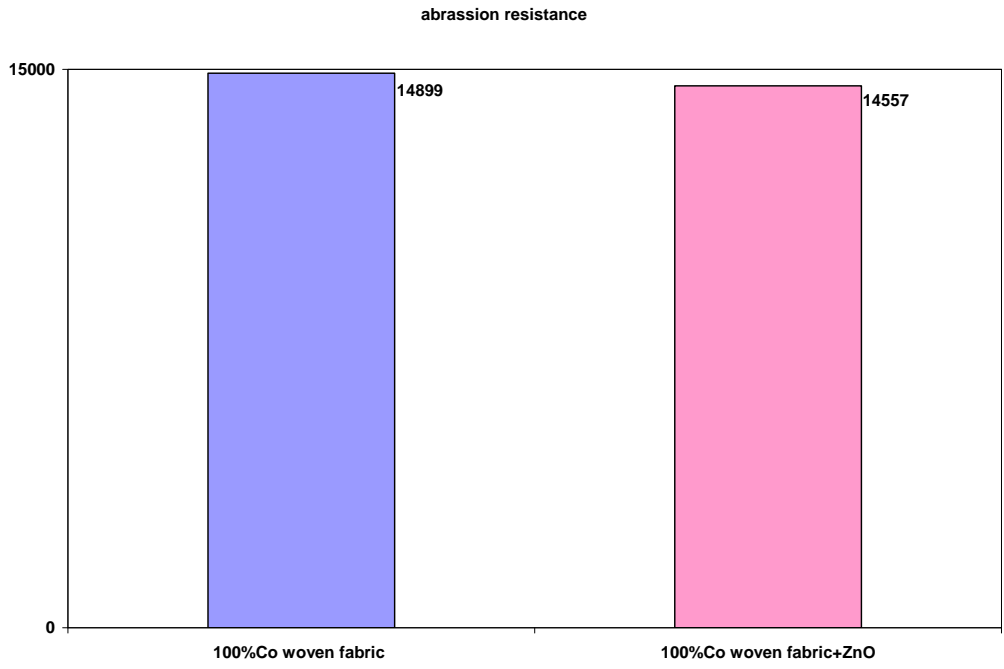


Figure 9. Abrasion resistance (cycles) for the 100% Cotton and 100% Cotton + ZnO

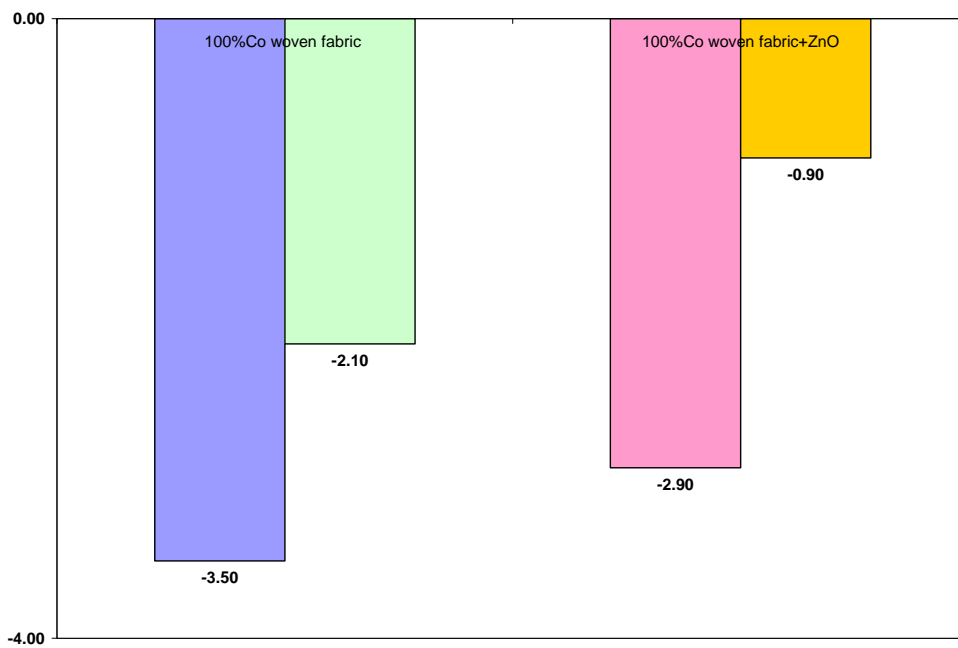


Figure 10. Dimensional stability (%) at washing for the 100% Cotton and 100% Cotton + ZnO

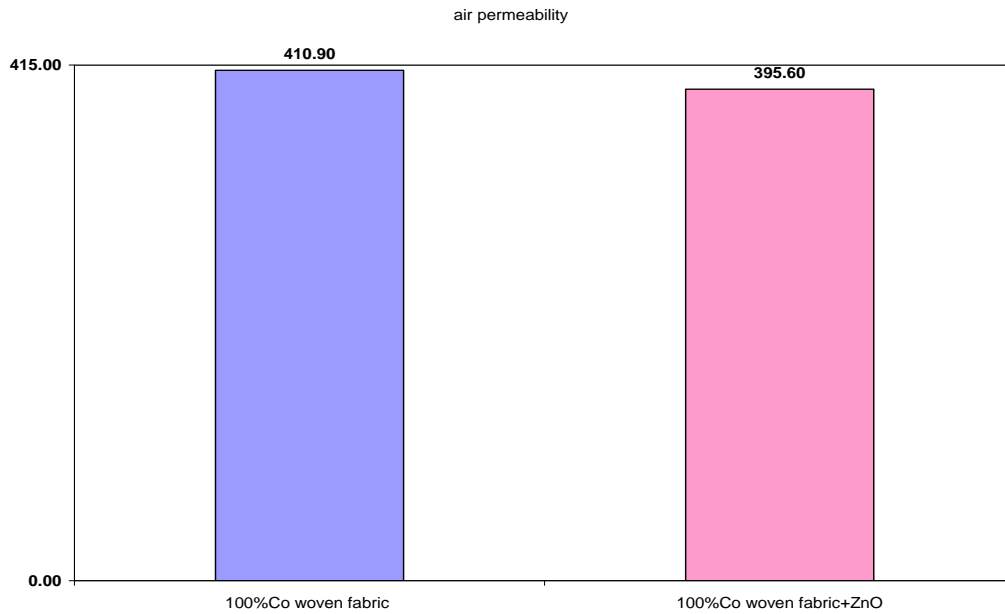


Figure 11. Air permeability ($l/m^2/sec$) for the 100% Cotton and 100% Cotton + ZnO

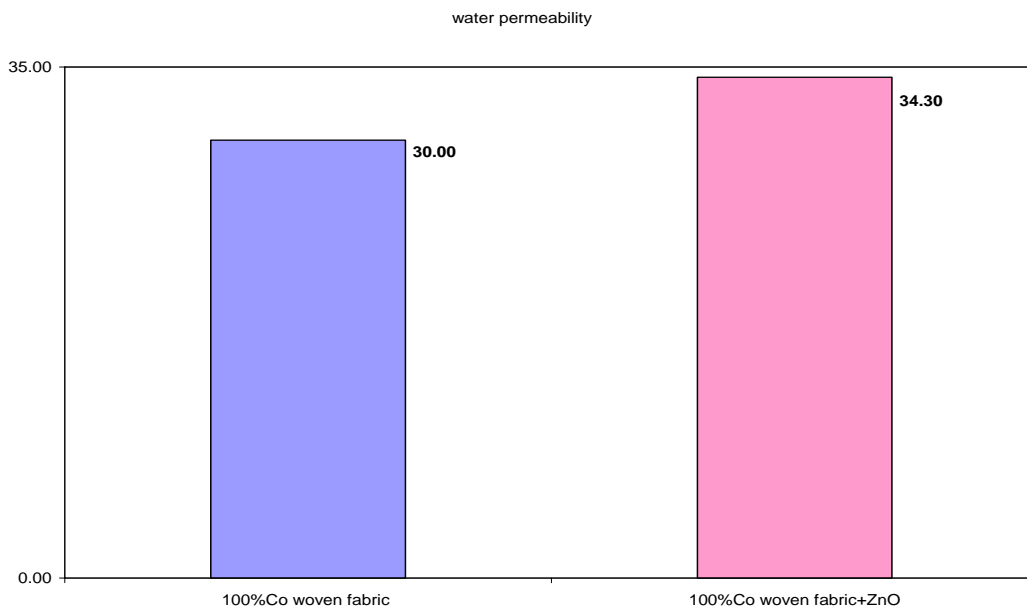


Figure 12. Water permeability (%) for 100% Cotton and 100% Cotton + ZnO

3.2 Scanning Electron Microscopy

In the figures 13 and 14 the morphological aspect for the Davo ZnO sample and the measurement of the ZnO nanoparticles are presented. It was used a Quanta 200 SEM, produced by FEI. It can be seen the wide distribution of the zinc oxide nanoparticles with the dimensions between 400 – 700 nm.

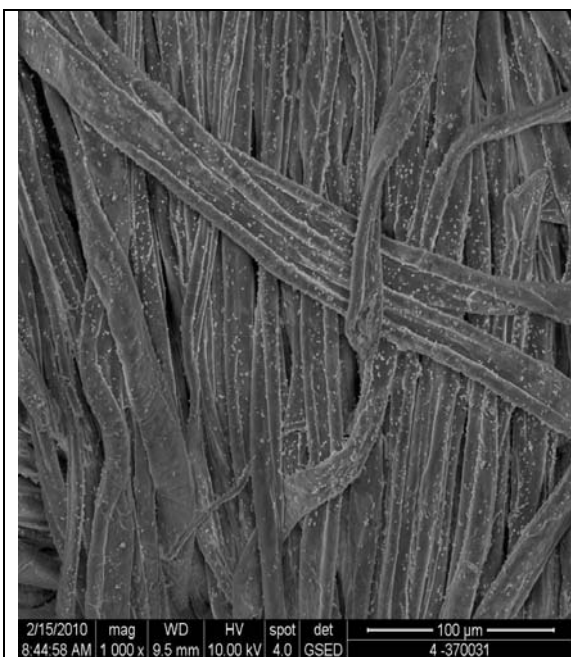


Figure 13. Morphological aspect of the Davo ZnO sample

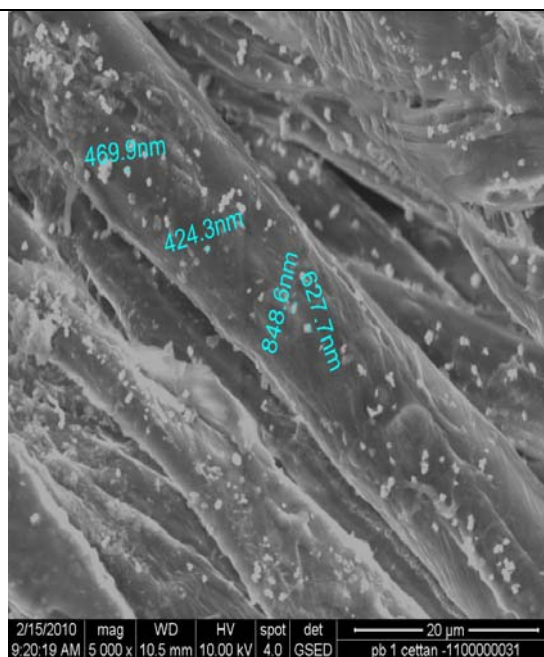


Figure 14. Measurement for the zinc oxides nanoparticles

3.3 Leaching in washing and perspiration floats

In tables 1- 2 the results for the leaching of the nanoparticles in the floats from washing and perspiration are presented. The measurements were made on an atomic absorption spectrophotometer (AAS, 880 Varian). It can be observed that the migration of zinc oxide nanoparticles is bigger in alkaline perspiration as compared with the acidic perspiration and also in washing with ECE detergent as compared with the washing in the ultrapure water.

Table 1. Leaching in the perspiration floats for the cotton 100% + ZnO

Sample	ZnO, mg/L	ZnO released in sweat solution, mg/Kg material	ZnO remained on material, mg/Kg material
alkaline	57.26	2863.13	6136.87
acid	5.305	330.5015	8669.4985

Table 2. Leaching in the washing floats with ECE detergent for the 100% cotton and 100% cotton + ZnO

Specimen	Sample	No. of washing cycles	Zn and ZnO released in washing floats				Zn and ZnO remained on the material, mg/Kg material
			Zn, mg/L	ZnO, mg/L	Zn, mg/Kg material	ZnO, mg/Kg material	
1'	100% Cotton	1	0	0	0	0	0
2'	100% Cotton + ZnO	1	8.4744	10.559	401.48	500.244	399,756
3'	100% Cotton	10	0	0	0	0	0
4'	100% Cotton + ZnO	10	5.471	6.8168	279.91	348.767	551,233
5'	100% Cotton	20	0	0	0	0	0
6'	100% Cotton + ZnO	20	9.8373	12.257	459.8	572.910	327,09

Table 3. Leaching in the washing floats without ECE detergent for the 100% cotton and 100% cotton + ZnO

Sample number	Sample	No. of washings	The amount of Zn and ZnO released in ultra-pure water				Zn and ZnO remained on the material	
			Zn, mg/L	ZnO, mg/L	Zn, mg/Kg material	ZnO, mg/Kg material	ZnO, mg/Kg material	ZnO, %
1	100% Cotton	1	0	0	0	0	0	0
2	100% Cotton + ZnO	1	0.3688	0.46	37.46	46.67	8953,33	99.48
3	100% Cotton	10	0	0	0	0	0	0
4	100% Cotton + ZnO	10	0.933	1.16	52.45	65.35	8934,65	99,27

3.4. Differential Scanning Calorimetry

In the graphs 15 – 17 the thermal curves obtained in a DSC equipment (DSC Pyris Diamond, Perkin Elmer) are presented, the first graph being for 100% cotton

sample and the last two for 100% cotton + ZnO. The program was set for heating the sample with 10⁰C per minute from 35 at 600⁰C, with a stationary phase of 2 minutes at 600⁰C.

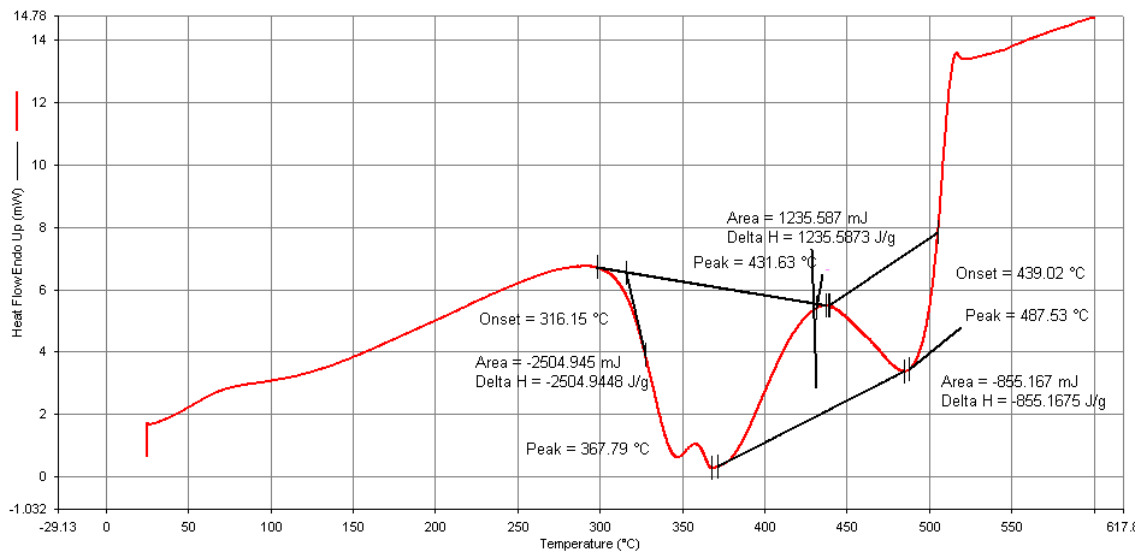


Figure 15. DSC Curve for 100% cotton sample

The 100% cotton sample presented 3 peaks at the 367,79 ⁰C; 461, 63 ⁰C; and 487, 53 ⁰C. The chemical processes that take place are represented by the decarboxylation of the cellulose and cellulose decomposition.

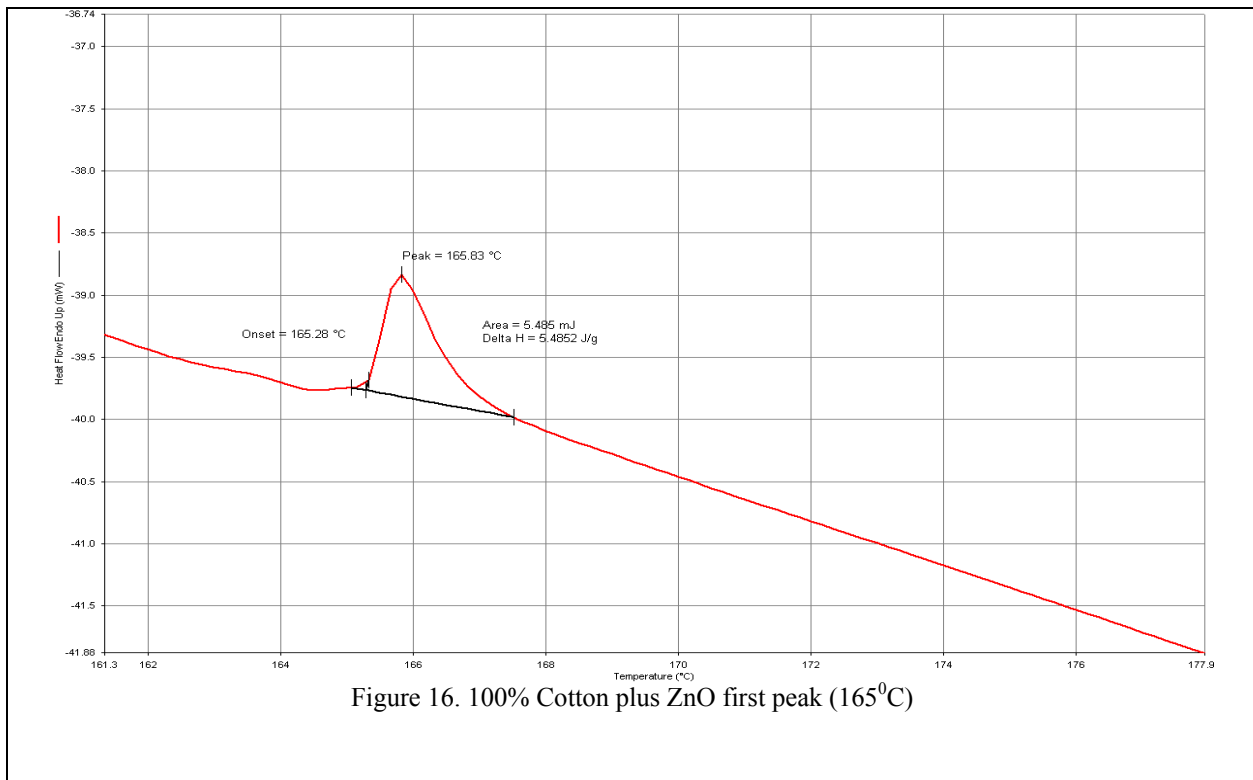
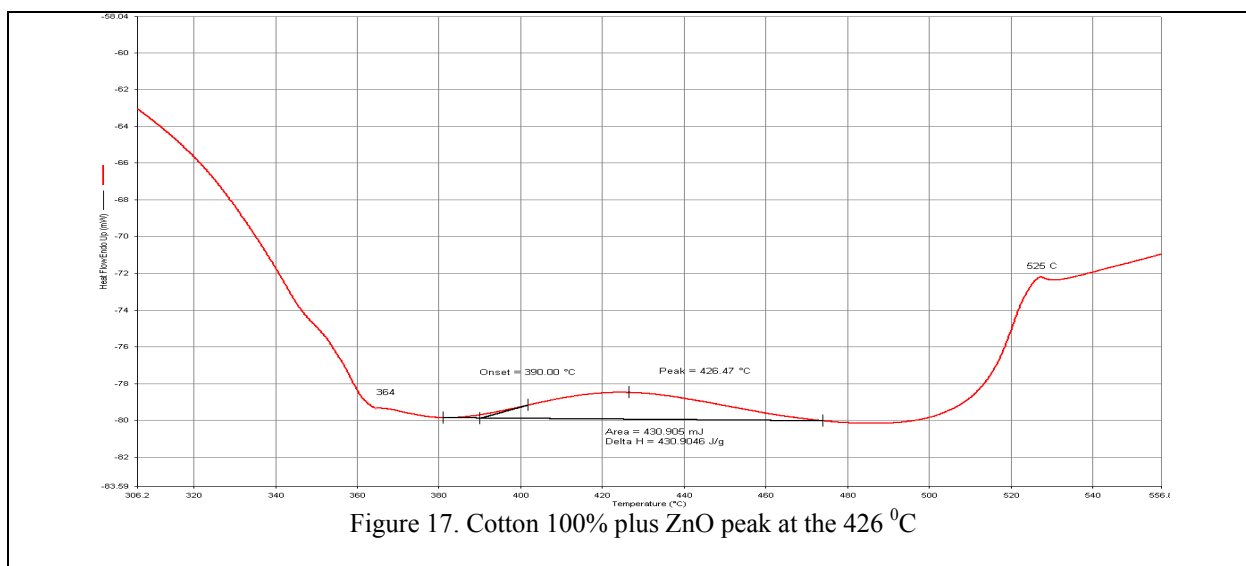


Figure 16. 100% Cotton plus ZnO first peak (165⁰C)



For the 100% cotton + ZnO sample the first endothermic peak is at 165 °C being due to bonding water loss or ethanol. The decomposition peak from Figure 17 at 426 °C degrees is weak because it is produced at the same time with the exothermic crystallization of ZnO.

3.5. Antifungal testing

The antifungal testing was done in accordance with SR EN 14 119 standard “Testing of textiles. Evaluation of the action of microfungi”. The strain used for determining the antifungal effect was *Aspergillus niger* IMI 45551. The inoculum was mixed with the Czapek-Dox medium and the samples cut at a 3 cm diameter were placed in the centre of the Petri Dishes. The incubation was done at 28 ± 2 °C for 14 days. Evaluation was done at 3, 7 and 14 days for both sides of the sample.

Figures 18 and 19 show the growth of the fungal mycelium on the samples.

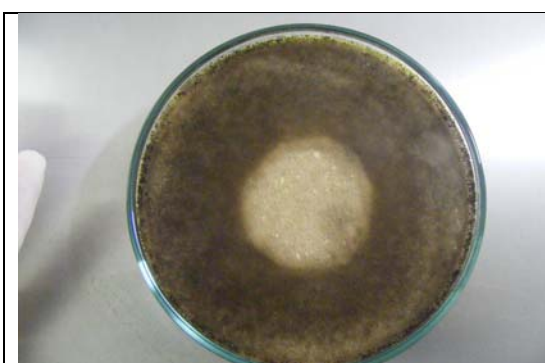


Figure 18. Antifungal evaluation on Cotton 100%



Figure 19. Antifungal evaluation on Cotton 100% + ZnO

4. DISCUSSIONS AND CONCLUSIONS

Two types of samples were analyzed: cotton 100% and cotton 100% + ZnO in order to observe the influence of the treatment realized in an ultrasonic installation with zinc oxide nanoparticles on the textile structure and properties.

The analyzed characteristics support the fact that the treatment with zinc oxide nanoparticles does not modify the main textile characteristic though they prove their adherence on the textile substrate.

Both the specific mass and the thickness of the textile were insignificantly modified. From a technological standpoint the bigger value of the thickness is considered an advantage. These two characteristics make a point for the nanoparticles: there are wide distributed, as shown in the SEM photos, without changing the basic textile parameter.

The next characteristics prove the effect of zinc oxides deposition, from the mechanical point of view. Thus, the breaking force increases through a local stiffening of the threads of almost 5 %, proved also by the elongation at break which is lower for the cotton 100% + ZnO and by the angle of creasing which is lower for the same sample, cotton 100% + ZnO.

These analyses show the transfer of the advantages of the nanoparticles from *micro* and *nano* level (the fiber structure) to significant variations of the physical- mechanical characteristics: breaking force, elongation at break, recovery from creasing of the *macro* level, variations which are though not big.

The abrasion parameter modification is not significant, and thus demonstrates that by wearing there is no nanoparticles loss.

The air permeability difference between cotton 100% and cotton 100% + ZnO is also insignificant, the advantage of using nanoparticles is maintained and increased by the water permeability parameter that has a bigger value for the cotton 100% + ZnO, because zinc will facilitate water absorption.

The DSC thermal curves and also the SEM micrograph prove the nanoparticles deposition.

The evaluation of the functionalization given by the nanoparticle deposition was done by the antifungal testing. The result showed yet that the fungal strain developed after 14 days of incubation. Other more sensitive methods need to be used for testing the antifungal effect.

These experiments were a primary characterization of a well known type of material, in order to prove the effect of zinc oxides nanoparticles. The ultrasonic deposition did not modify significantly the physical-mechanical characteristics, and the variations appear at the significance limit.

More research will follow on a wide variety of raw materials, fibrous compositions and textile structures.

Acknowledgement

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HEMP FIBER: AN ECO-FRIENDLY ALTERNATIVE

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Key Words: Hemp, organic textiles, environmental pollution

Abstract: *Environmental pollution and global warming have become a major problem for the world. Many researches are carried out to prevent this situation. Each industry branch has its own solution proposal for this problem. When the textile industry is considered, organic textiles seem as a present solution. Hemp fiber is very suitable for organic textile production, since hemp plant can grow with no fertilizers or agriculture chemicals. Hemp fiber also has superior daily usage performance in addition to its ecological benefits. It aims at investigating these features of hemp fibers and at highlighting the importance of sustainable hemp textile production.*

1. HEMP PLANT

Hemp is an annual woody plant which belongs to the cannabinaceae family. It has various species. Cannabis sativa variety is cultivated for industrial purposes such as fiber obtaining. Hemp has been used for textile production since ancient times [1-2]. A picture of cannabis sativa field is shown in Figure 1.



Figure 1. Hemp field [10]

Nowadays, there is a huge demand of hemp textiles on the global market. This interest depends on superior ecologic and daily usage properties of hemp fiber [3].

2. ECOLOGICAL PROPERTIES OF HEMP

Organic agriculture has in view a sustainable production without harming the environment that shall transfer a protected environment to the next generation. Organic agriculture is highly controllable. Synthetic fertilizers and agriculture chemicals are banned in organic agriculture [4].

Hemp is very suitable for organic production. Hemp plant can grow without fertilizers, agriculture chemicals and extra water. Also, hemp is suitable for crop rotation [3-5].

3. USES AND PERFORMANCE OF HEMP FIBERS

Hemp fibers have high strength, moisture absorbing, breathing, anti pilling, UV protecting properties. Also, hemp is an antibacterial fiber [3-6-7-8-9].

Hemp fiber has wide range of uses in textile industry. Hemp is used for garment production such as shirts, jackets, pants, skirts. Also, hemp fiber is used for home textiles such as curtains, covers, carpets, mats [3].

Hemp fiber is also suitable for composite production. Automotive industry uses hemp fibers to produce composite body parts. Hemp fiber is also used in construction sector as insulation material [3]. Modern uses of hemp plant are shown on Figure 2.

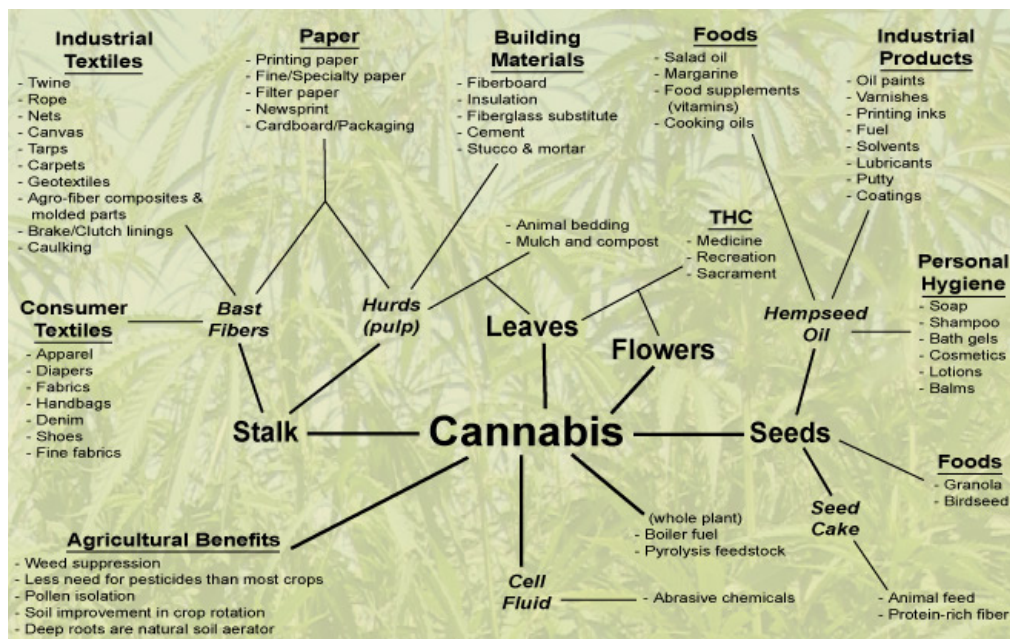


Figure 2: Schematic representation of modern uses of hemp plant [11]

4. CONCLUSION

Textile industry is one of the most criticized industries due to the environmental issues. The most consumed natural fiber cotton needs a lot of agriculture chemicals and extra water and synthetic fiber production depends on petroleum products. When these situations were considered, hemp fiber draws attention with its organic production potential.

There are some limitations on hemp production due to the narcotic concerns but cannabis sativa is not used for drug production. Cultivation of cannabis sativa and production of hemp fiber for textile purposes should be encouraged for a better ecological future.

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Tex-EASTile – European Network for green textile excellence
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Keywords: sustainable innovation, green marketing tools, sustainable networking

ABSTRACT:*The aim of this paper is to present the on-going research project “Tex-EASTile : sustainable innovation for textile in South East Europe ” (2009-2012) funded by European Union under Transnational Cooperation Programme South East Europe .*

The mission of the project Tex-EASTile is to create a new synergy between the public and private sector in order to disseminate knowledge, to promote the application of eco-design tools and to spread product sustainability principles in manufacturing productions and consumptions, encouraging the Public Administrations to purchase them.

Tex-EASTile foresees the involvement of SME of the textile sector in 6 different countries of South East Europe European region. The aim is to foster the exchange of good practices and innovative tools targeted to quality and environmental certification of production and products. In these terms, Tex-EASTile also supports the implementation of pilot projects. Tex-EASTile aims to raise awareness among Public Administrations on eco-sustainable principles applied to contracted works and services (Green Public Procurement) and the project also aims at providing Public Administrations with best practices to make the “greening” process easier in public consumptions.

The purpose of Tex-EASTile is to establish a community of excellence to improve the offer of “green” textile in the market, supporting, in particular, the innovation of production and distribution processes in order to reduce their environmental impact.



ECO-FRIENDLY POLYAMIDE DYEING BY RECYCLING WASTEWATER AFTER OXIDATIVE TREATMENT

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Keywords: polyamide dyeing, colour removal, hydrogen peroxide, Fenton-like catalyst, recycling

Abstract: *The possibility to recycle textile wastewater produced in acid polyamide dyeing processes is investigated in this study. In the first stage wastewater from the dyeing process and the wash-off wastewater were decolorized using hydrogen peroxide activated with catalysts from resins functionalized with amines and saturated with Cu (II). The treated wastewater was used as it is or mixed with fresh water in new dyeing processes of polyamide. The residual hydrogen peroxide was removed from the wastewater prior to subsequent dyeings. Reflectance, colour difference, the colour parameters of the CIELAB colour space (L^* , a^* and b^*) and the wash fastness have been determined. It was found that oxidative discoloration is a feasible solution, especially for low dye content wastewaters. In order to recycle dyeing wastewater careful consideration has to be taken regarding the temperature, pH and chemical content.*

1. INTRODUCTION

As the water resources of the planet are scarcer and scarcer and increasingly polluted, the reuse or recycling of industrial wastewater became a major investigation topic.

The textile industries produce high quantities of effluent with varying composition depending on the nature of the fibre and the type of wet processes employed¹, water consumption varying between 3 dm³/kg and up to 835 dm³/kg. Recycling wastewater for textile dyeing and finishing after an appropriate treatment is a solution to reduce the water consumption and, in addition to this, it was proved to result in savings in water, energy and chemicals². In most cases, textile wastewater is coloured, so the wastewater can be recycled in new finishing or dyeing procedures only after decolourization processes.

Many methods have been used to remove the colour of textile wastewater, among which the most studied are the membrane filtration, sorption, coagulation/flocculation, membrane and electrochemical and oxidative methods³. None of these methods proved to be effective in all cases, and there are supplemental difficulties in terms of cost and technological and practical considerations⁴. A method that leads to good results is the advanced oxidation, method which provides good results in removing the colour of most dyes, acid dyes included⁵.

The purpose of this study was to evaluate the feasibility of the process of recycling wastewater from dyeing of polyamide in new dyeing stages, after removing colour by oxidative means. The basic goal was to arrive at a treatment system that would lead to a

minimum of 90% reduction in the colour of the wastewater, and provide recycled dye baths dyeings with a colour difference less than 1 unit comparing with the standard.

2. MATERIALS AND METHODS

Two half milling acid dyes have been used: Acid Blue 113 (disazo) and Acid Green 9 (triphenyl methane), both supplied by Bezema. The chemical structure of the dyes is shown in figures 1 and 2. These dyes have been tested without previous purification.

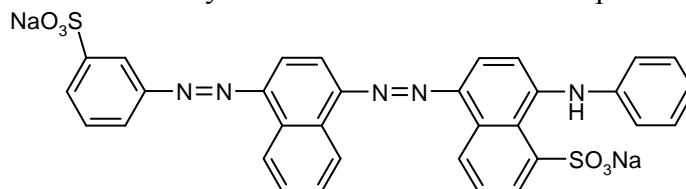


Figure 1. Chemical structure of Acid Blue 113

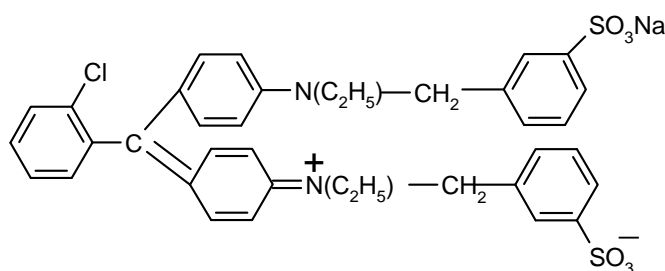


Figure 2. Chemical structure of Acid Green 9

100% scoured polyamide fabric, weight 130 g per meter has been used for all the experiments.

All dyeing processes have been performed in an Ahiba lab dyeing machine.

For the discoloration of wastewater hydrogen peroxide solution (Merck, 30% w/w) has been used. To activate the hydrogen peroxide decomposition, catalysts from resins functionalized with amines and saturated with Cu (II) have been used. The colour removal experiments were conducted at 50°C temperature and reaction time was of 60 minutes; the volume of treated solution was 250 mL.

The colour removal degree, expressed in percentage, had been calculated from the relative decrease of absorbance, according to relation (1), where Abs_0 is the absorbance of the initial and Abs_f is the absorbance of the final solution to the absorbance of the initial solution.

$$\% \text{ Colour Removal} = \left(\left(1 - \left(\frac{Abs_f}{Abs_0} \right) \right) \right) * 100 \quad (1)$$

All absorbance measurements were made by a UV/VIS Camspec M501 spectrophotometer, at maximum absorbance wavelength (566 nm for Acid Blue 113 and 633 nm for Acid Green 9).

The pH values were detected by a COLE PARMER pH/mV meter.

The CIELAB Colour Difference used to measure colour differences in samples was calculated by the following equation:

$$DE^* = [(dL^*)^2 + (da^*)^2 + (db^*)^2]^{1/2} \quad (2)$$

A DATACOLOR Spectroflash SF-300 spectrophotometer has been used to measure the

colour parameters, the colour difference and the degree of whiteness of the polyamide samples dyed with recycled water. D65 – day light standard illumination condition, large area view, specular included have been used. In order to obtain a high opacity of the sample, each sample was folded twice with four. The washing fastness was determined according to SR EN ISO 105 - CO6/1999.

3. EXPERIMENTAL

In the first stage of the research, synthetic wastewater has been used to analyse the colour removal process using hydrogen peroxide in the presence of Cu based Fenton-like catalyst.

In order to prepare the synthetic wastewater, 50 ppm of acid dye and 600 ppm sodium sulphate were dissolved in distilled water in a 1 dm³ Erlenmeyer. These values are corresponding to the composition of a wastewater produced in a dyeing process at liquor ratio of 1:50 and an exhaustion of 80%.

The discoloration experiments were carried out according to the methodology that proved to offer optimal results in previous studies: 0,5 mL hydrogen peroxide 30%, activated with 0,06 g catalyst, have been added to 50 mL of wastewater samples (adjusted with NaOH to pH 9) and the treatment continued for 60 minutes.⁶ Two treatment temperatures have been tested: 20°C and 50°C.

Subsequently, wastewater from real dyeing and the wash-off wastewater have been treated at 50°C using the mentioned oxidative technology, and the treated wastewater has been recycled as it is or mixed with fresh water (1:1) in new dyeing processes of polyamide. The diagram of the dyeing process is shown in fig. 3⁷, and the codification of the recycling experiments is presented in table 1.

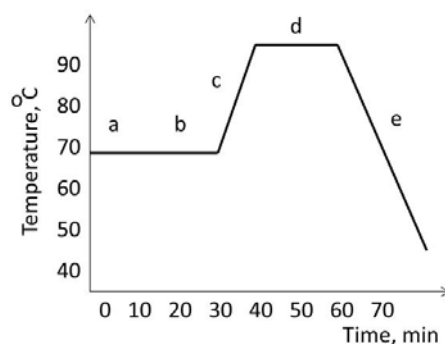


Figure 3. The dyeing process of polyamide: a = prewetting; b = acid addition (3% owf - percent on weight of fabric- acetic acid); c = heating; d = setting; e = rinsing.

Table 1: Experiments codification

Dye conc., %	Wastewater type	Recycle variant*	Number
Standard			1
1	dyeing	a	2
		b	3
	rinsing	a	4
		b	5
3	dyeing	a	6
		b	7
	rinsing	a	8
		b	9

*a – as it is; b – mixed with fresh water (1:1)

Previous research shown that in oxidation discoloured wastewaters some residual oxygen

peroxide remains, which significantly affects new dyeing processes⁸. In order to remove the residual oxygen peroxide an anionic reducing agent has been used.

New dyeing processes using treated wastewater were realised with the same dye as in the initial dyeing. Since the electrolyte (sodium sulphate) was available in the treated wastewater, the dyeing with the decolourised dyeing wastewater was carried out without any supplemental sodium sulphate and the dyeing with the dyeing treated wastewater mixed with fresh water was carried out by adding 50% of the initial sodium sulphate quantity. pH values of each recycled wastewater were adjusted to the starting pH values using acetic acid.

Reflectance, colour difference and the colour parameters of the CIELAB colour space (L^* , a^* and b^*) have been determined. L^* represent the lightness of the colour and is the vertical coordinate of a three-dimensional system of colours, which has values from 0 (black) to 100 (for white), a^* is the horizontal coordinate ranging from green to red, and b^* is the horizontal coordinate that ranges from blue to yellow⁹.

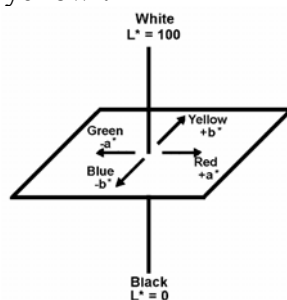


Figure 4. CIELAB space

4. RESULTS AND DISCUSSION

The results for the discoloration of two acid dyes as obtained by the Fenton-like process are shown in figure 5. After only 30 minutes at 50°C it was achieved up to 95% colour removal from the dye solution of both dyes, while at room temperature the colour removal degree was under 70%. Therefore, is advisable to treat wastewater immediately after the dyeing process (while still warm).

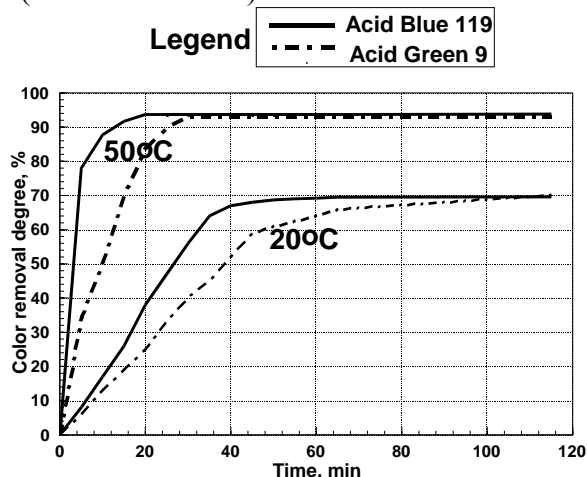


Figure 5. Variation in time of colour removal at two treatment temperatures

Figure 6 shows the reflectance variation for the samples dyed with Acid Blue 113 using recycled wastewater, and figure 7 presents the colour difference between the dyed samples and the standard.

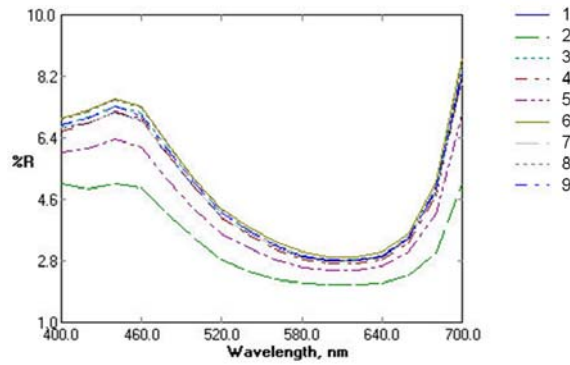


Figure 6. Reflectance of samples dyed with 1% Acid Blue 113 using recycled wastewater (after discoloration and removal of the hydrogen peroxide excess)

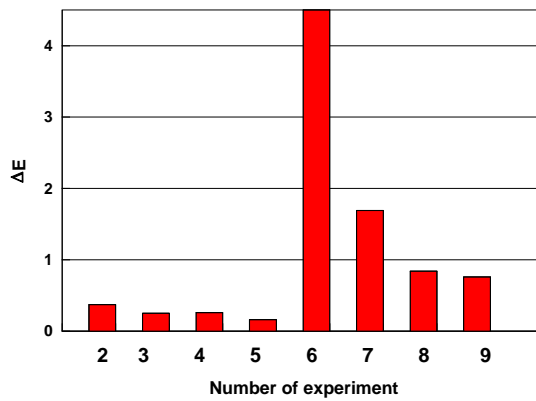


Figure 7. Colour difference for the samples dyed with 1% Acid Blue 113 using treated wastewater

For the majority of the recycling variants, the DE^* values were in the acceptable range of about 1 unit, and this proves that the decolorized wastewater did not undesirably affect the dyeing process. It can be seen that in the case of the 1% dyeing wastewater, for all the recycling variants the colour difference is even smaller than 1/2 unit (variants 2 to 5).

On the other hand, for the 3% dyeings, the colour differences are much bigger, especially for the dyeing wastewater (variants 6 and 7), even after mixing it with fresh water. Better results have been obtained when using the treated wash-off wastewater (variants 8 and 9).

Besides the colour difference dE^* , in order to identify colour deviations, the coordinates of the CIELAB colour space L^* , a^* and b^* of the standard and the dyed samples were calculated and plotted in figure 8.

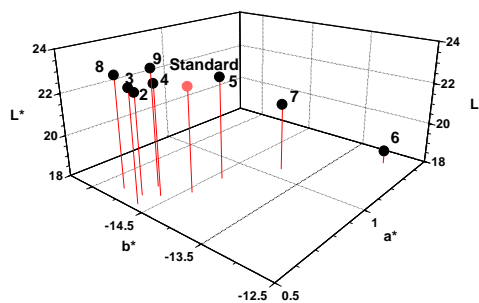


Figure 8. CIELAB parameters for 1% Acid Blue 113 dyeing using treated wastewater after removing the hydrogen peroxide excess

It can be observed from figure 8 that for the samples that showed big colour differences

(variants 6 and 7) there is a significant shift towards red (bigger a^*) and yellow (bigger b^*), and the smaller L^* values indicate that they are darker in colour than the standard, while the samples corresponding to the other variants show only a minor shift towards green, without any colour darkening.

Washing fastness properties of the samples dyed with Acid Blue 113 using recycled wastewater are shown in table 2. It can be seen that all the samples have good washing fastness (even identical to the standard for the samples dyed with mixed recycled rinsing wastewater and fresh water – samples 5 and 9).

Table 2.

Number of experiment	Washing fastness
Etalon	5/4-5/4-5
2	4-5/4/4-5
3	4-5/4/4-5
4	5/4/4-5
5	5/4-5/4-5
6	4-5/4/4
7	4-5/4-5/4-5
8	4-5/4/4-5
9	5/4-5/4-5

The results obtained for the dyeing processes made with 1% Acid Green 9 using treated wastewater are shown in figures 9 – 10. In all cases, previous to the new dyeing the excess of hydrogen peroxide has been eliminated.

From figure 9 it can be seen the reflectance variation for the samples dyed with Acid Green 9 using recycled wastewater, and figure 10 shows the colour difference between the dyed samples and the standard.

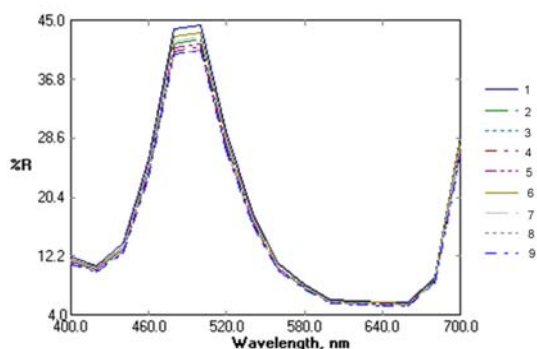


Figure 9. Reflectance of samples dyed with 1% Acid Green 9 using recycled wastewater (after discoloration and removal of the hydrogen peroxide excess)

The results obtained show that, with the exception of variants 6 and 7, the colour differences are bigger than the ones for Acid Blue 113, but they are in the accepted interval of 1 unit. As it was to expect, the smaller colour difference is obtained for variant 5, when treated wash-off wastewater mixed with fresh water has been used. Even for the wastewater generated in the 3% dyeing the colour difference is very close to the limit of 1 unit (1,04 and 1,09 respectively), and visually there are no colour differences.

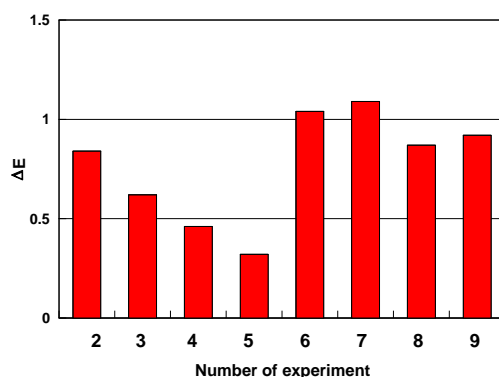


Figure 10. Colour difference for the samples dyed with 1% Acid Blue 113 using treated wastewater

In order to identify the existence of colour shifts, L^* , a^* and b^* have been plotted, as it can be seen in figure 11.

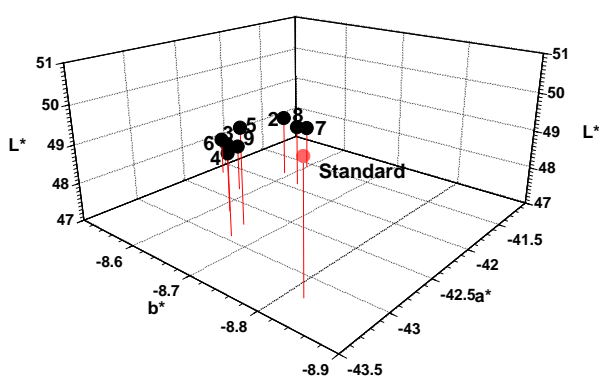


Figure 11. CIELAB parameters for 1% Acid Blue 113 dyeing using treated wastewater after removing the hydrogen peroxide excess

From figure 11 it can be observed a slight colour shift towards red (bigger a^*) and on a smaller scale towards yellow (bigger b^*). These tendencies are more obvious for variants 6 ($db^* = 0,3$) and 7 ($da^* = 1,65$). It is to notice a significant decrease of L^* values, meaning that the samples dyed with recycled wastewater are darker (variants 6 and 7 lead to the bigger differences – 2.05 and 1.84 respectively), while variants 4 and 5 (wash-off recycled wastewater) show the smaller differences in lightness (0,55 and 0,99, respectively).

Table 3 shows the washing fastness properties of the samples dyed with Acid Green 9 using recycled wastewater. No modification in washing fastness can be observed, even for the 3% dyeing wastewaters (variants 6 and 7), which proves that the recycling process does not affect the wash fastness.

Table 3

Number of experiment	Washing fastness
Standard	5/4-5/5
2	4-5/4-5/5
3	5/4-5/4-5
4	4-5/4-5/5
5	5/4-5/5
6	4-5/4/5
7	5/4/5
8	5/4/5
9	5/4-5/4-5

5. CONCLUSIONS

On the basis of the experimental data obtained, it can be concluded that the use of hydrogen peroxide activated with resins functionalized with amines and saturated with Cu (II) efficiently removes the colour of wastewater produced in dyeing processes using Acid Blue 113 and Acid Green 9.

The reuse of the oxidative discoloured wastewaters from polyamide dyeing showed small colour differences compared to standard. It was concluded that oxidative discoloration is a feasible solution, especially for low dye content wastewaters. For higher concentration wastewater, only recycling after mixing with fresh water leads to acceptable colour differences. In all cases, the washing fastness was not affected by the recycling process.

In order to recycle dyeing wastewater careful consideration has to be given to the temperature, pH and residual hydrogen peroxide elimination.

The payback on the wastewater recycling depends on the degree of constructional changes needed, and the number of times the recycling can be performed.

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HUMAN RESOURCE MANAGEMENT IN THE TEXTILE - CLOTHING INDUSTRY IN ROMANIA

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Keywords: human resources management, the Romanian textile-clothing industry, domestic and global market competition

Abstract: *At the macroeconomic level, endogenous growth theories suggest that the accumulation of human capital is the main engine of economic growth. The increasing importance of human capital is determined by the development of information and communication technologies, and especially by the shift towards the "knowledge-based economy." As a result, human resources are better educated, they assimilate a greater volume of information and knowledge and they develop high intellectual capacities.*

The pattern of the enterprises in the textile industry in Romania - mostly SMEs - includes centralized control, the owner being in the center. Limited financial and organizational resources require human resource management to be an amateur activity. The small business tends to be direct and informal, the character of the entrepreneur determines the work climate, the moral conduct of the employees, and the entrepreneur-manager controls all major functions.

It is to be noted that the practices of companies in our country are generally not oriented towards developing and promoting its own production, but rather to providing outsourced manufacturing, few staff dedicated to sales and marketing and, also, to the research and development of new products.

In this paper, research results on human resources in the textile-clothing industry in Romania are presented, as a result of sectoral project no. 24/2008-2010, entitled "The Romanian textile-clothing industry in the European and global context: Strategic elements regarding increasing competitiveness of the sector in the conditions of domestic and global market competition"; to this purpose a quantitative research was done on a group of Romanian firms from the textile-clothing industry.

INTRODUCTION

The importance of the human resource is never stressed enough. According to Professor Aurel Manolescu[†], human resources are unique as regards their potential for growth and development, as well as their ability to know and overcome their own limits, in order to face the new challenges or current and future requirements.

Human resources are the only unlimited resource of creativity, solutions and new, authentic and valuable ideas. People design and create goods and services, they control quality, they allocate resources, make decisions and, above all, establish or develop objectives and strategies. All other categories of business resources are important and useful,

[†] Manolescu A., Managementul Resurselor Umane, Ed.a patra, Editura Economică, București, 2003

but human resources and their management are very important and valuable in facing the unknown. The distinctive characteristic of work resources is that this is the only resource that produces, creates and develops the perspective of continuous innovation in production.

As regards importance, the management of human resources is clearly distinguished and delimited from the other functions of the enterprise and components of the management as a whole. The explanation resides in that the human resource management is the association of two resources: the manager and the management, on one side, and the work resource, on the other side; both resources have the same human origin, the highest form of matter, life organization; no other resource or resource association may be compared to the association represented by the management of human resources.

Countries that reached a high level of economic development position management include the human resource management among the most important factors of economic growth.

The development of new economies in the Asia-Pacific region showed some light over the weak points of traditional management methods in western countries. In order to be able to compete with the new competition from Eastern Asia, **industries and organizations from the more developed countries were forced to reorganize, to create a high-performance management of human resources.**

The specific nature of activities in human resource management in the textile-clothing industry organisations

Human resource management is the human activity of organizing and conducting scientifically based principles, norms and cultural values, methods, techniques and tools for the forecast, recruitment and allocation of labor resources, quantitative and qualitative modeling and development in terms of motivation, safety, hygiene and protection, in line with the aspirations and interests of employees and the business goals of rationality, efficiency, and maximum competitiveness.

Obviously, the nature of human resource management varies a lot, but the general trend in Romanian textile industry business – mostly SMEs – is characterized by the **model where the owner is in the center**, a model that aims for a centralized control in small size companies:

- Limited financial and organizational resources require that the human resource management be an amateur activity;
- The small company tends to be direct and informal, the character of the entrepreneur determining the climate and the morale of the work force;
- The employees have poorly defined responsibilities and reduced authority;
- The entrepreneur-manager controls all major functions; work tasks, wages and benefits are negotiated with him;
- The entrepreneur-manager is the one that employs and fires, determines wages and the work conditions and requests maximum flexibility from the workers.

As regards strategy, there are few situations of long term planning. Decisions are made when problems appear. Personnel development and training are often neglected. Career development and planning are rare. Performance measurement is rudimentary and arbitrary.

Crisis management

Employees have to be flexible and ready to work on demand. They have to fulfill a multitude of tasks without necessarily be trained for them.

Companies with less than 50 employees usually do not have a distinct function of

human resource. **The employee function**, a characteristic of SMEs defines its:

- ✓ *Coverage area*, through human resource management done by the entrepreneur/small management team;
- ✓ *Coherence*, dependent of the entrepreneur's personality;
- ✓ *control*, completely centralized
- ✓ different *communication*, the objectives not being clear;
- ✓ *competences*, dependent on the abilities and knowledge of the entrepreneur and perhaps on those of a small number of employees;
- ✓ *creativity*, most SMEs are imitating their competition;
- ✓ *cost efficiency*, given the conditions of few employees with small wages.

Study regarding human resources in romanian textile-clothing companies

The theoretical aspects stated above are sustained by economists and researchers based on studies undertaken in large projects[‡] that have started from the premise that the activity of companies in our country is not generally oriented towards developing and promoting of their own production and rather towards providing outsourced production. This is supported by the small staff dedicated to sales and marketing and also to research and development of new products. The study on **employee structure** in textile industry companies shows the following:

- national average number of persons belonging to the **Department of Administration and Management** is rather low, normally specific to small and medium enterprises. It should be noted that although this department should mainly be composed primarily of people with higher education, specific to the textile industry, economy and management, their share in the department according to the country average is a third (32.45 %).

However, an exception to this are the companies from the South-East of the country, Bucharest and Ilfov, with a share of about 50% and the west area with a share of 61.6% of employees with higher education from the total of the employees in the Administrative and Management Department. According to the analyses, the Southern part of the country is recording the lowest percent of employees with higher education in all companies' Administrative and Management Departments of just 16.03 %.

From the point of view of the importance of the share of the Administrative and Management Department in the total of employees from the textile industry we observe that the percentages vary from 3% in the Southern region to 5% in the North-Eastern region, 6% in the Western, 7% in Bucharest – Ilfov, 9% in the South and 10% in the Central.

- the production activity involves the use of employees that do not require higher education and the collected data are relevant in this respect. As share in the total number of companies' employees, **production departments** are the largest, the country average indicating approximately 251 employees (82%), as opposed to 4 employees in the research-development department (1.3%), 20 in the administrative-management department (6.52%), approximately 6 employees in the sales-marketing department (2%), 10,5 in the quality control department (3.43%), less than 1 employee in the department for textile waste monitoring and environment protection(0.32%), and approximately 13.5 employees in other departments (4.43%).

- regarding the **sales-marketing activity**, an interesting fact is revealed by the structure of the employees in this department. Thus, although the sales-marketing departments do not require outside collaborators and their number does not include workers, yet they are composed of technicians (69,5%), rather than people with higher education

[‡] Sectorial project „The Romanian textile-clothing industry in the European and global context”, 2008-2010

(30,5%), the only areas where the percentages are relatively balanced are found also in Bucharest-Ilfov (50% technicians - 50% higher education) and in the West (58,8% technicians - 41,2% higher education). The central part of Romania is the area mostly deprived of qualified personnel with higher education studies in the departments of sales-marketing, the share being of 22% higher education and 78% technicians. Of course, for the activities of sales-marketing, as they are one of the most important directions for company development, the adequate personnel should have higher education studies and market analysis training, product promotion training and less technical training, but the collected data indicate an anomaly in this regard country wide and mostly in the Center. A relatively low number of employees are allocated to **sales-marketing departments** in all 6 regions in Romania that were studied. Thus, the largest share of sales-marketing employees in the total number of company employees is in companies in the Western area of Romania – 4%, followed by Bucharest-Ilfov and the North-East – 3%, other regions: Center, South and South-East having 2% of all employees dealing with contracts-sales-marketing. Of course, the number of people working in this important department of the company is very small for the company to develop its own brands in local and foreign market, but this information reveals that the factories in Romania are subcontracted by larger producers and that these are long-term, constant partnerships, with orders returning regularly, having explicitly mentioned specifications, that do not require a very complex design, research and development activities.

- the country average employee number in the **research, design, development department** indicates a much lower number of employees in comparison to the administrative-management department (fig.1). Thus, if in the latter the country average is 20 employees, in the case of the research, design, development department, the average is 4. The Southern region of the country allocates the smallest number of employees to research and development (an average of 1.16 which is less than a third of the country average). Above average values are in companies in Bucharest and Ilfov (average of 5.57 employees) and in the North-Eastern area (average of 6,6 employees). The share of the employees in this department expressed as a percentage of total company employees puts the companies in Bucharest-Ilfov in front of the other regions, with 4% of the employees, followed by the companies in the West, Northeast and Southeast with 2%, while the companies in the South and Center do not usually allocate personnel for this activity. Surprisingly, at national level, the personnel with advanced training and higher education only holds a share of 35%, almost half of the employees in the research-development department being workers. In this case, too, the companies in Bucharest, Ilfov, West have the largest share of employees that are adequately trained for this department (higher education and technicians), the percentages being of 87.25% and 72.67%, respectively. If in the administrative and management department of Romanian companies 5.35% are collaborators, and in the case of Southern and Bucharest-Ilfov companies the percentage goes up to 13.46%, and 16.4%, the same phenomenon doesn't occur in the research, design, development department. Here, companies prefer using their own personnel, although small in number, and thus the share of collaborators in this department tends to zero at national level.

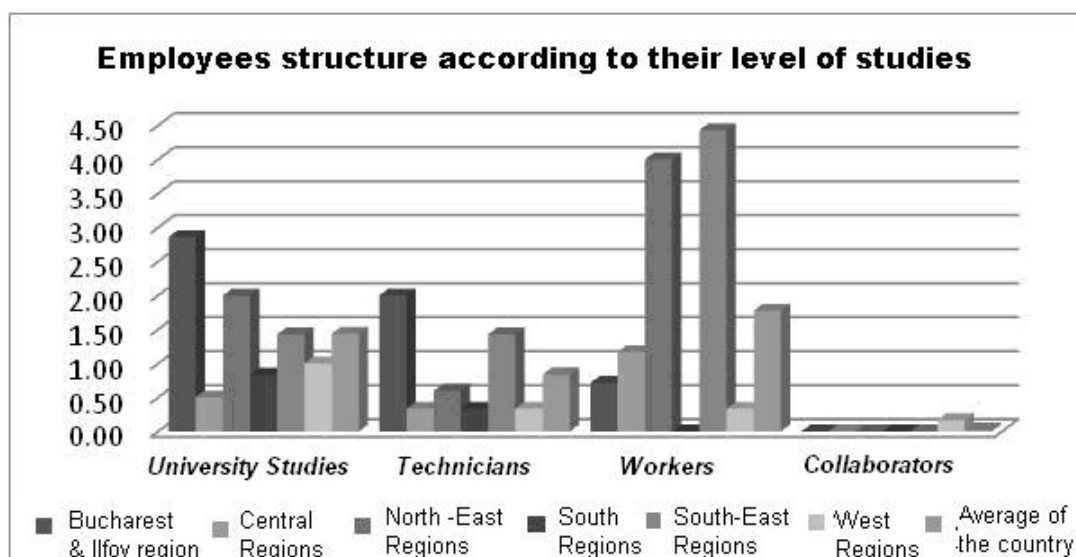


Fig.1 – R&D employees structure according to their level of studies

- in turn, **the quality control department** is mainly represented at national level by workers (56,3%), but also technicians (35,2%) and employees with higher education (3,5%). Deviations from this average are recorded in the Central and Western areas where the technicians significantly exceed the number of workers in this department: 70% - 25%, respectively 65,3% - 13%. For quality control the distribution is relatively uniform from the point of view of the number of employees that companies allocate for these activities: Bucharest-Ilfov, West, Northeast - 4%, and the Central, Southern and Southeastern regions 3%.

- **the department for textile waste monitoring and environment protection** is poorly represented in number of persons, an important share of them being higher education employees, followed by technicians. In a similar manner to case of the quality control department, the concern – or better said the lack of concern - for textile waste monitoring and environment protection assigns almost the same percentage of employees to deal with the specific processes in all 6 regions. Thus, except for the companies in Bucharest-Ilfov and the Western region, that assign 1% of their total employees to deal with textile waste monitoring and environment protection the other regions do not assign personnel for these activities.

- the other **departments** have a reduced share of employees, the categories of professional training being represented in a proportional manner, 15% higher studies, 26,7% technicians, 56,3% workers.

By analyzing the personnel structure employed in companies from the textile industries we can conclude that regions that are based mostly on innovation and development are Bucharest-Ilfov and the West, but also Northeast, while the factories in the Central and Southern regions process more orders of outsourced production.

Based on data obtained from the research, a **coefficient of correlation** was calculated to observe whether there is a **connection between the region and the personnel structure**, but denied the existence of a correlation between the personnel structure and the area where the business activities take place.

Also, as regards personnel structure employed in the textile industry, the analysis shows that **the employees are mostly females**, in percentages that vary between 70 to 100%, depending on region.

In analyzing the personnel employee in the textile industry, it was observed that **the most important share is represented by the age group 36-45 years – 74%**, people that have

experience in the field and that are trained for the activities they carry out (fig. 2). The following age group is 46-65 years with 18 % and then 26-35 years with 8 %. The absence of personnel of age group 18-25 years shows that the young people in this age group are not drawn to this industry, on one hand because of the lack of professional training and on the other hand probably because of the reduced earnings.

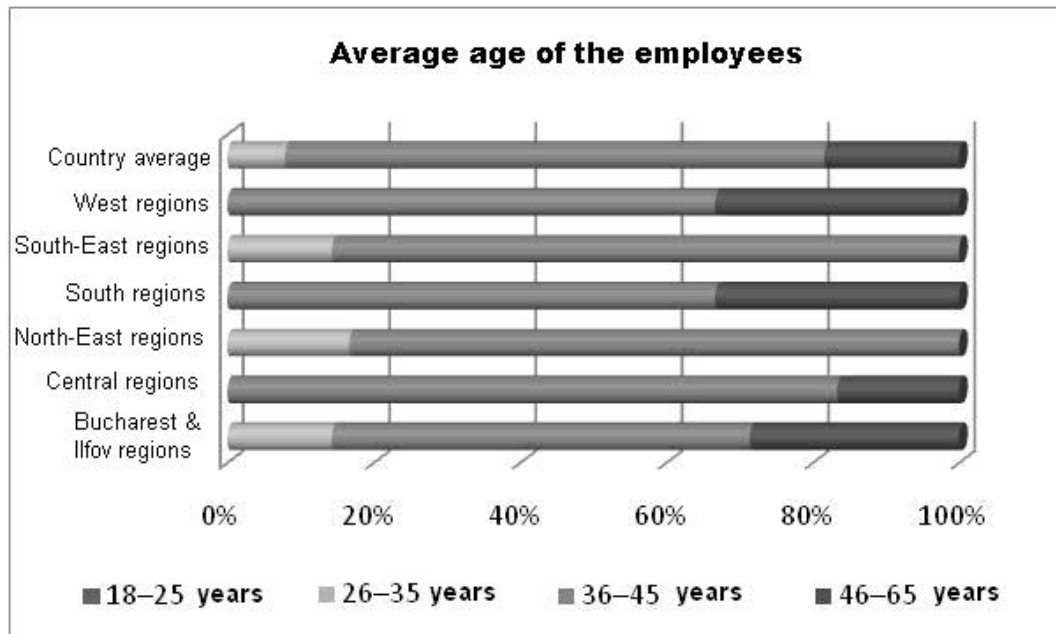


Fig.2 – The average age of people employed in textile sector

Also to be noticed is the fact that the Bucharest-Ilfov region has the lowest share in the age group 36-45 years as compared to the North-Eastern, Central or South-Eastern regions. A peculiarity is noted in the Central and Southern regions where the age group 26-35 years is missing. On the other hand, in the Central region the share of employees within the age group 36-45 years is larger than the country average, going up to 83%. The same thing does not apply to the Southern region, where the absence of the age group 26-35 years leads to an increase in the percentage of employees with ages between 46-65 years up to 33%, a value almost twice as large as the country average. High values of this age group are also registered in the Bucharest-Ilfov region – 29%, while the surveyed companies in the Western and the Southeastern regions said that the share of employees in this age group tends to zero. One can observe that the average age of employees in the textile industry is between 35 and 46 years old. We conclude that this is due to the fact that in this industry, the personnel must be provided with specialized training and work experience. It is also noticeable the fact that the age group under 25 years is not present, which shows the lack of concern for training personnel for this activity. Also, the age of the employed personnel may reflect the economic situation of different geographical regions in Romania. Thus, in the Southern and Bucharest-Ilfov regions, both areas with more developed economic activity and where middle-aged population of up to 45 years old can be employed in better paid fields of activity, due to the pressure of competition and international market demands, the textile industry offers the lowest salaries. Despite this, at the national level, 70% of employees have maintained their workplace. Surprisingly, this analysis shows that the Southern region, where a third of employees are between 46-65 years old and 67% between 36-45 years old, the level of fluctuation is the highest – 66,67%. Personnel turnover according to regions is considered to be low at the national level, the highest being registered in the Southern region and the lowest

in the Central region. In the Southeastern and Northeastern regions the fluctuations are the lowest. The perception regarding personnel turnover, at the national level, is appreciated as being reduced, which is normal if we correlate it to the age old of employees, and shows they are less inclined to change their workplace.

CONCLUSIONS

As progress towards knowledge-based economy and business takes place, on the background of maintaining and accentuating the rise of the systemic character of the organization's functions, it appears that some of these functions are of increasing importance, having an impact on organizational performance, slightly higher than in the classical capitalist company. In addition to product innovation and marketing, that are claimed to have become key functions of firms in the top branches of the economy, the human resources function, in particular through training activities, seeks and acquires a momentum and a considerable impact, given the company's transformation into a learning organization. As result, some experts refer to the training function by separating it from the human resource function and placing it at the same level as other well known functions: research and development, commercial.

Staff function refers to those tasks and duties, which take place both in large organizations and small, to provide and coordinate human resources.

Work resources bear the limited character of their quantitative potential and the characteristic of an unlimited potential, resulted in their qualitative side. The unlimited character is specific, not so much by way of regeneration (like other renewable resources), but by the unlimited horizons of creation that they exhibit in the history of mankind.

Providing training on a continuous basis to an organization's human resources involves considerable costs and this is one of the main reasons for the non-involvement of companies in the textile industries. On the other hand, other organizations, and most researchers in the field, consider continuous training of employees as a medium and long term investment with high returns.

Training the employees provides long term benefits, leading to the idea that it can be treated as providing dividends, a feature of many assets. The advantages provided by the continuous training of human resources are generally acknowledged, among which are: improving customer relations, workplace safety, profitability and organizational effectiveness, work climate, increase sales and reduce absenteeism, staff turnover and critical incidents. But perhaps the most important gain is the *competitive advantage*.

Continuous training of human resources fulfils all these criteria and can be considered, from this point of view, an investment.

Regardless of the training type, nowadays there is a general agreement in what concerns the necessity to stimulate the activities of training inside companies, as a long term investment. However, enterprises in the textile industry, in most cases, do not allocate funds for training, and a large number of them are not developing training activities for their employees. This situation is due to several factors:

- training is often regarded as insignificant for the enterprise;
- in periods of economic crisis, reducing the costs of an organization aim first to the training budget, considering training as a luxury that cannot be afforded during difficult times;
- the lack of practical aspects and effectiveness of various training activities.

In what concerns the personnel training, one can notice that there are concerns regarding this aspect, only when hiring and regular regarding workplace safety (83%), so in

general those that are mandatory, and relative to other formulations (professional improvement classes), the concerns are much more modest (17%).

82,85% of the employees are trained when they are hired and according to the law they are periodically trained regarding work safety but only 17,14% follow annual professional improvement classes, in connection to their basic activity. The Western part of the country invests the most in those professional improvement classes, 33,33%, and above average values are recorded also in the South, 28,57%.

As directions for action for improve the management of human resources in organizations from the textile-clothing industry we consider that firm and joint actions of Romanian political factors and the civil society are necessary, that will consider the quantitative and qualitative growth of consulting activities, training programs based on individual approach, as well as group development, programs based on a sectorial integrated approach, mentoring and tutoring.

From an economic perspective, as a consequence of the global crisis, one can observe the increasingly frequent phenomenon of growing unemployment rate. The reason for this is found in several cases, namely, on one hand the opening of the markets that allowed the creation of jobs only in the so-called cheap countries (from the area of Asia, South America and Eastern Europe and especially Russia), and on the other hand the development of technology has facilitated the setting up of businesses directly on the Internet, with low costs and considerable profits.

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DATABASE ON BIOCIDES FOR MATERIALS PROTECTION AGAINST BIODETERIORATION

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Keywords: Database, biocides, materials, protection, biodeterioration.

Abstract: *Scientific information has become the main resource for the development of modern society and therefore each educational institution must have an appropriate and flexible management in the sense that the scientific field should be effectively implemented. The success of scientific investigation and/or culture depends to a great extent on the quality and quantity of sources to which we have access in an institution.*

Referring to the biocides used for the protection of different materials, we need to know well enough the effect they may have on our health and environment, so we can minimize undesirable influences through their choice in full compliance with all requirements imposed. Biocidal products are active substances or groups of substances that prevent, neutralize and exert an effect control on any harmful organism by chemical or biological means.

1. INTRODUCTION

Scientific information has become the main resource for the development of modern society and therefore each educational institution must have an appropriate and flexible management in the sense that the scientific field should be effectively implemented. The success of scientific investigation and/or culture depends to a great extent on the quality and quantity of sources of information we have access to in an institution.

The purpose of this paper is to provide those interested with an analysis tool for the most common biocides used for the biosafety of various materials in several branches of industry.

For biocides used for the protection of different materials, we need to know well enough the effect they may have on our health and environment, so we can minimize undesirable influences, through their choice in full compliance with all the requirements imposed.

Various microbiocides are used for preserving materials in raw and semi-processed state and these have negative effects on the environment and living organisms. The textile and leather industry, among others, plead for the use of chemical preservatives with ecological properties. For different reasons, Romanian industries did not fully implement the use of organic preservatives to protect materials. People as consumers of various industrial products, must have access to all information about the biocides used to protect materials against biological deterioration and our database is an extremely important source of information for them.

2. BIOCIDES

Biocidal products are active substances or groups of substances that prevent, neutralize and exert an effect control on any harmful organism by chemical or biological means [1]. In Romania, preparation and marketing of biocides is regulated by the provisions of Governmental Decision no. 956 dated 2005, with modifications and further additions.

The role of biocides is to effectively preserve the different materials, namely:

- To maintain the material in good hygiene conditions, thereby reducing the harmful organisms (viruses, bacteria, fungi), the formation of odors due to biological degradation, the spread and transfer of pathogens. Figure 1 reveals how bacteria affect industrial processed animal skin, implicitly emphasizing the importance of biocides on the protection of materials. The main bacteria which lead to skin damage are: *Bacillus subtilis*, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Aerobacter* etc. [2]. Against them we can use different biocides with antimicrobial action.

- To prevent mold;
- To protect the material against decay.



Figure 1: Effect of bacteria on the skins

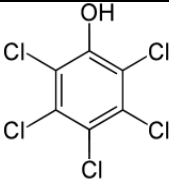


We collected information for more than 300 biocides, out of which 100 are textile and leather products. We have structured them as files, with 14 specific fields: substance class, chemical name, molecular formula and so on.

Biocides listed in our database were divided into 22 classes of substances out of which the most important are: alcohols, aldehydes, phenols, acids, amides, azoles, organometallic compounds etc. Table 1 presents the file of a biocide used in textile and leather industries.

The following abbreviations were used in Table 1:

- CAS-No = Chemical Abstracts Service number
- EC-No. = The European Commission number
- EINECS-No. = European Inventory of Existing Commercial Chemical Substances number
- pKa = negative logarithm of the acid
- K_{ow} = log octanol-water partition coefficient
- log K_{oc} = Soil sorption coefficient
- LC = Lethal concentration
- LD = Lethal dose

Table 1: Information on Pentachlorophenol

Substance Class	HALOGENATED PHENOLS	
Chemical name	Pentachlorophenol	
Other names	PCP; PCP(pesticide); Chlorophenasicacid; Dowicide 7; Fungifen; Penton 70; Santofen; 1-Hydroxypentachlorobenzene; Permasan	
Molecular Formula	C ₆ HCl ₅ O	
Structural Formula		
Codes	CAS-No.: 87-86-5; EC-No.: 201-778-6; EINECS-No.: 201-778-6	
History:	PCP occurred, first in 1930 and can be found in two forms: self-PCP or PCP sodium salt, which dissolves easily in water.	
Manufacturing method	PCP can be produced by chlorination of phenol in the presence of a catalyst, to about 191 °C and result in 84-90% purity PCP.	
Chemical and physical properties [3]		
Molecular mass, g/mol	266.34	
Appearance	odorless white or light brown powder or crystals	
Content, (%)	~ 99	
Boiling point, °C	310 at 101 kPa	
Melting point, °C	191	
Density, g/ml (191 °C)	1, 978	
Vapor pressure, hPa	5. 1 x 10 ⁻⁵ at 20 °C	
Value pKa	5. 26	
log K _{OW}	5.12	
log K _{OC}	4.52	
Stability	very stable under normal conditions	
Solubility, g/l (20 °C)	Slightly soluble in water: 0.02 in H ₂ O; soluble in organic solvents and alkaline media	
Toxicity / Ecotoxicity [4] [5]		
	Log K _{OW} and log K _{OC} values show a strong sorption in soil. PCP is highly toxic, difficult to biodegrade and bioaccumulate in organisms. Contact with PCP irritates skin, eyes and mouth. PCP is carcinogenic and highly toxic by inhalation.	
LD ₅₀ oral	150 mg/kg rat	
subcutaneous	100 mg/kg rat	
percutaneous	96 mg/kg rat	
intraperitoneal	56 mg/kg rat	
LC ₅₀ inhaled	355 mg/m ³ for rats	
LC ₀	0. 2 mg/l for fish	
Symbols of danger alert	 N Dangerous for the environment  T+ Very Toxic	
Antimicrobial efficiency [6]		
	PCP exhibits strong algicidal effectiveness in concentrations of 2.5-5 mg/l.	
Applications in industry: textile and leather, wood, paint, construction		
	PCP is used in leather industry for preserving products made of cotton or other natural cellulosic fibers, avoiding the formation of mold and rot. The final product must not contain more than 0.5 ppm of PCP, due to its high concentration of chlorine. PCP is used in Romania for fireproofing and wood treatment. Because of toxicity, ecotoxicity and persistence biocide, now steps are to replace the PCP in accordance with Directive 1999/51/EC [7].	

3. EXPERIMENTAL WORK

We have a large amount of information but this cannot be properly understood unless we have a database type application, enabling rapid processing and sorting information, their extraction on various search criteria (toxicity, antimicrobial activity, application field such as: textile and leather industries, plastics, cosmetics, pharmaceutical, food, environment etc).

We designed and developed a database (DB) with useful information for most biocides which can be supplemented with other new substances.

The database has a public character, being accessible online for researchers, teachers, students, doctoral students, producers, and generally for anyone wishing to obtain specialized and complete information on these substances.

We developed a relational database, from the conceptual model for the analysis of the application of biocides [8]. Entity-Relationship Diagram (ERD) used is shown in Figure 1.

Substances are included in the database in the form of entity (represented in rectangles), with specific attributes - a plain key PK (marked with a hash), a series of mandatory attributes (marked with an asterisk) and a series of optional attributes (marked with a circle).

Attributes of the substances included as fields with information about each biocide, are structured as follows:

- The chemical name in accordance with internationally accepted nomenclature;
- Commercial names;
- Biocide Classes of substances;
- Chemical and structural formula;
- Code numbers: CAS EC-No., EEC-No., EINECS-Nr. and other code numbers;
- Biocide applications (including textiles and leather protection);
- Information on the antimicrobial action of the biocide on the bacteria, yeasts, fungi.

The database includes a file for each substance; this file can be downloaded in PDF format, with more details (physical and chemical properties, information about toxicological and eco-toxicological behavior, the history of discovery and the application fields of the substance, methods of manufacture/production of biocide, its inclusion in a class of chemical hazard represented by specific symbols).

To normalize the DB into the first form (1NF), we transformed all attributes with multiple values into distinct entities (such as associated codes of a substance, their applications, equivalent names etc.), related with the first by foreign keys (FK). We did not use composite primary key, therefore the database is in the second normalization form (2NF). There are no transitive dependences between the attributes of an entity, which makes our DB to be in the third form of normalization (3NF).

In addition, we split the many-to-many (M:M) relationships by including a new entity of intersection. For example, a substance may have several applications, while an application corresponds to more than one substance. The original diagram shows a relationship M:M between the entity SUBSTANCE and TYPE_OF_APPLICATION. We have split this relationship, introducing the entity APPLICATIONS with its own identifier.

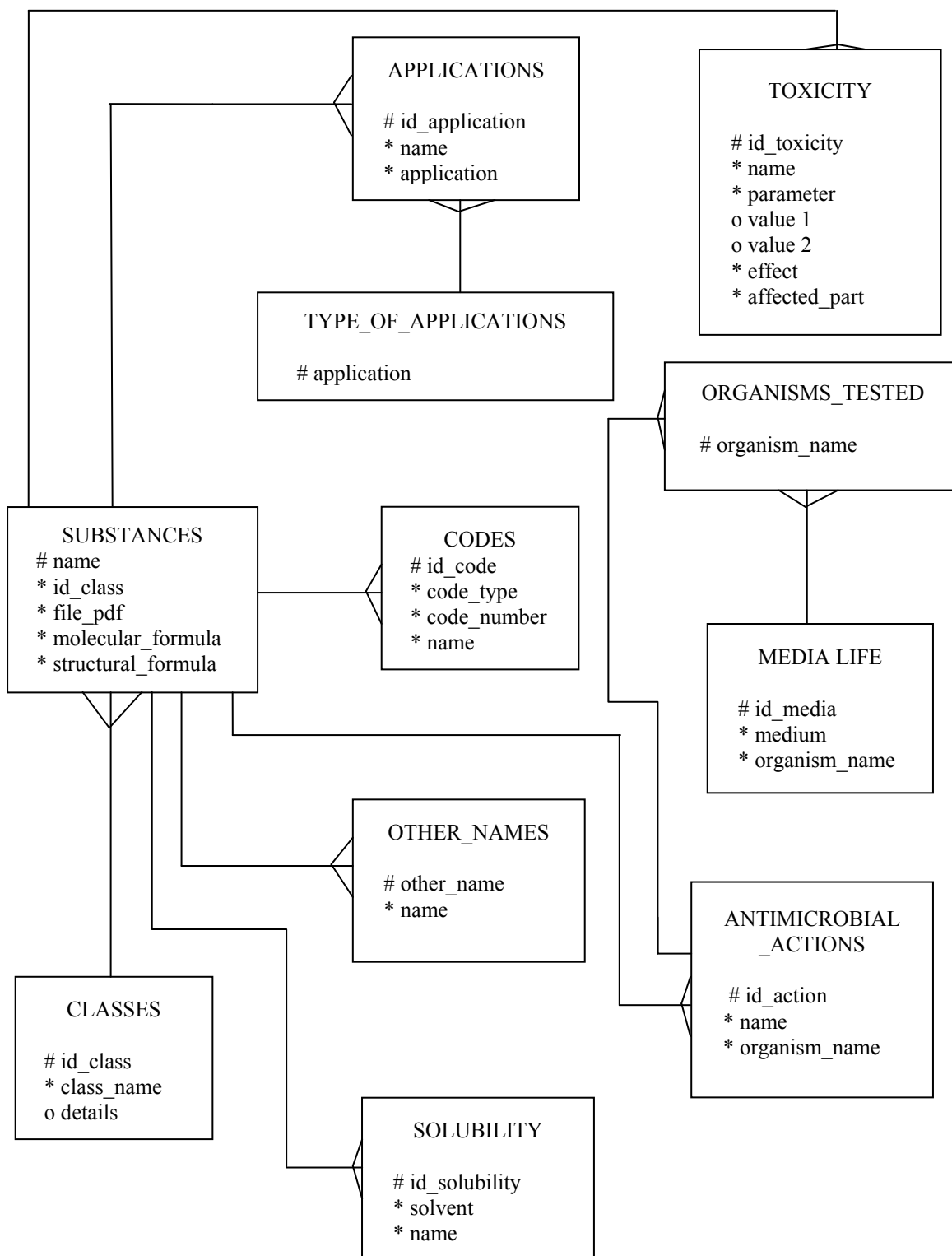


Figure 1: Entity-Relation Diagram

There have been kept unchanged one-to-many relationships (1: M) like: CLASS - SUBSTANCES, SUBSTANCE - CODES, SUBSTANCE - ANTIMICROBIAL_ACTIONS. Based on ERD diagram, we realized physical model of DB: we defined the tables of DB associated of entities and data type and size for each attribute of the entities.

Some of them are string type with variable length (VARCHAR) and with maximum size required (for example, the name of the substance), others are numeric type (DECIMAL, INTEGER) like the identifiers or some values of the parameters or file type (BLOB).

Based on this diagram ERD, we realized physical model of DB: we defined the tables of DB associated of entities and data type and size for each attribute of the entities.

Some of them are string type with variable length (VARCHAR) and with maximum size required (for example, the name of the substance), others are numeric type (DECIMAL, INTEGER) like the identifiers or some values of the parameters or file type (BLOB).

Implementation of the database is made in MySQL language with access interface from a web page in PHP language. Forms were used for entering data and they were created in PHP [9].

In web page, users can perform the following queries:

1. What substances are in the class <class_name>?
2. What is the chemical name of the substance known as <other_name>?
3. What substance does the code type <code_type> with the number <code_number> refer to?
4. What substances have application in <application>?
5. What substances have antimicrobial action against <organism_name>?
6. What substances are soluble in <solvent>?
7. What substances are toxic to <affected_part>?
8. What substances can be used to purify <medium>?
9. What is the substance with the molecular formula <molecular_formula>?

The secure access to the database is achieved by defining multiple user groups, with different rights based on roles.

Access to the database is conditioned by creating a user account, with a username and a password and the e-mail address of the user, useful to inform him about the news on the DB.

Visitors have the right to read the information provided by the DB by external views, created on basis of one or more tables. This total revoking of visitor rights on all tables in DB is a security measure adopted by us to protect data and the structure of DB.

Some tables extracted from DB are presented in Figure 2. The arrows reveal the links which are created between them.

4. CONCLUSIONS

We must know that all chemicals, regardless of how they are used, affect our environment to a certain extent and therefore it is necessary to know their effects.

Biocides used to protect materials represent an important segment of the industry and it is necessary to know their effects in order to prevent the destruction of the ecosystem we live in but at the same time to understand the importance of removing microorganisms that lead to biodeterioration of the material in question.

By exploiting the information provided in this database we can draw conclusions on how the antimicrobial action of biocides on different materials, on toxicity and ecotoxicity so we can manage the potential risks of biocides.

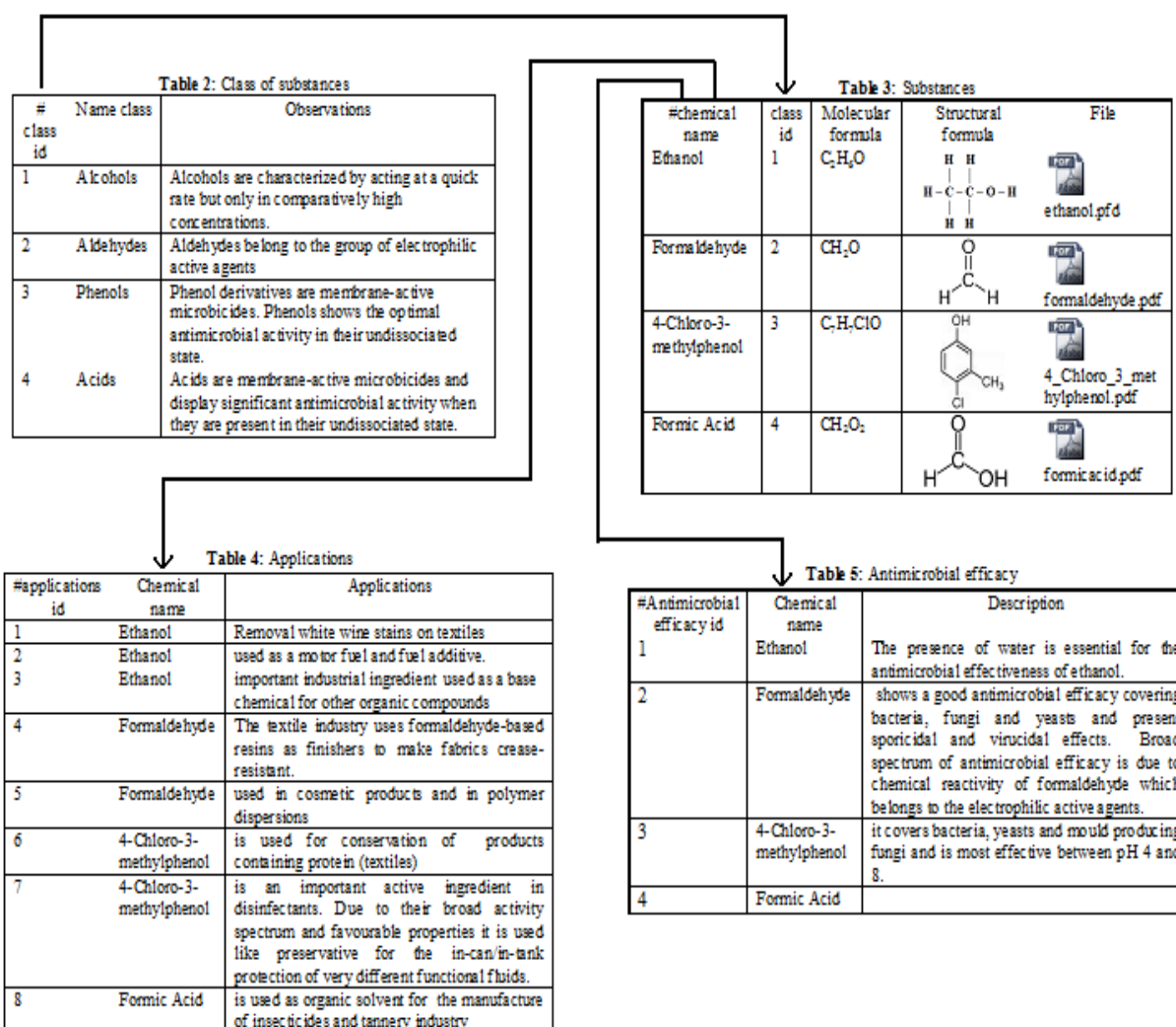


Figure 2: Some tables in DB

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NEW PERSPECTIVES IN E-COMMERCE AREA FOR GARMENT PRODUCTS

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Keywords: Textile, garment, e-commerce, simulation, design, 3D.

***Abstract.** This paper presents the new perspectives in using the e-shop for mass customization, marketing or garment product commercialization. The e-commerce is the place where the customer can search the products that are in accordance with his needs. The e-commerce for retailers means new alternatives to sell the products, a new challenge to present products in an attractive way. The e-shop shows the products items characteristics and the alternative to see how a product looks like.*

1. INTRODUCTION

The e-shop helps the customer diminish uncertainties that generate some questions relating to:

Is it the correct size?

Is the simulated product close to reality?

Is the imprint played correctly?

Does the colour represent the real colour?

Would I really look like this in the virtual dressing room?

This e-shop is based on client-server model (figure 1). The e-commerce is the development area for sellers. The buying and selling products processes over electronic systems like the internet and other computer networks is a simple way keep in touch the demand and supply of garment products (figure 2). A large area of e-commerce is conducted entirely electronically for virtual items such as access to premium content on a website, but most electronic commerce involves the transportation of physical items in some way. The retailers from online business are sometimes known as e-tailers and online retail is sometimes known as e-tail. All big retailers have electronic commerce presence on the World Wide Web.

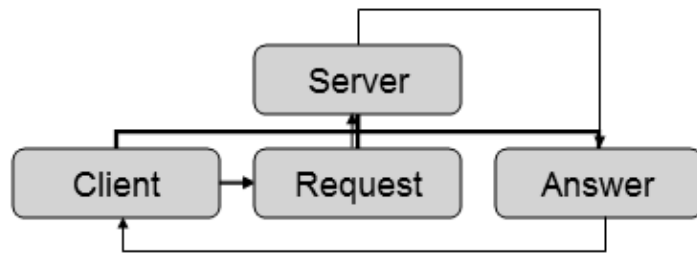


Figure 1: Client – server model¹

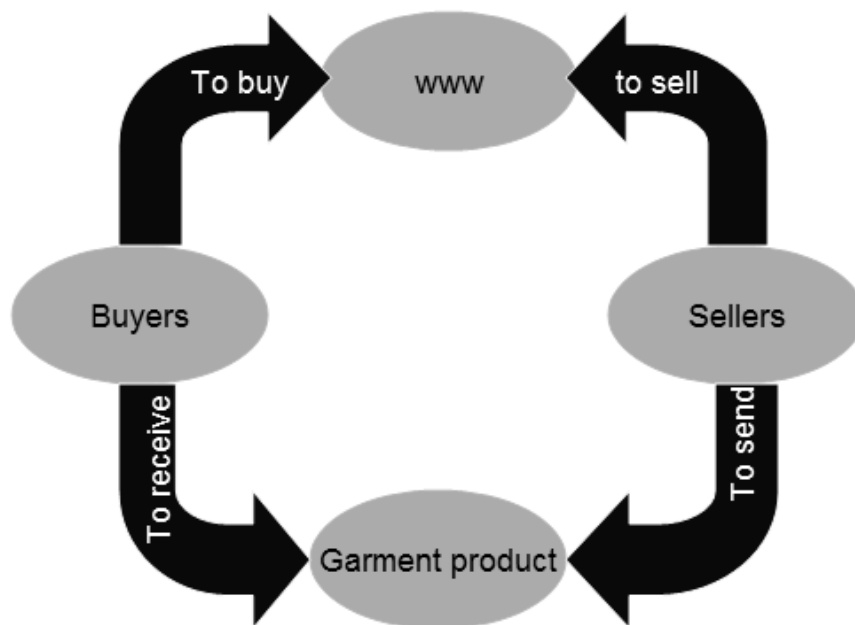


Figure 2: The e-commerce area: Seller’s offers and buyers’ requests

2. E-SHOP – CLIENT SIDE PRESENTATION

The e-shop is presented as 3D room where the buyer enters, chooses the clothing model, colour and textile material and head to the fitting room where is generate the garment simulation¹. In the fitting room he has two options¹:

- The first is to upload the 3D body scanned file (figure 3) if he have one.



Figure 3: 3D body scan file upload

- The second is to use the parametric mannequin by setting his measurement values (figure 4).



Figure 4: Parametric mannequin loading

If the customer chooses the parametric mannequin loading then he must choose his body size. The dressed body simulation (figure 5) is shown when all fields required are completed (product type, color and textile material).

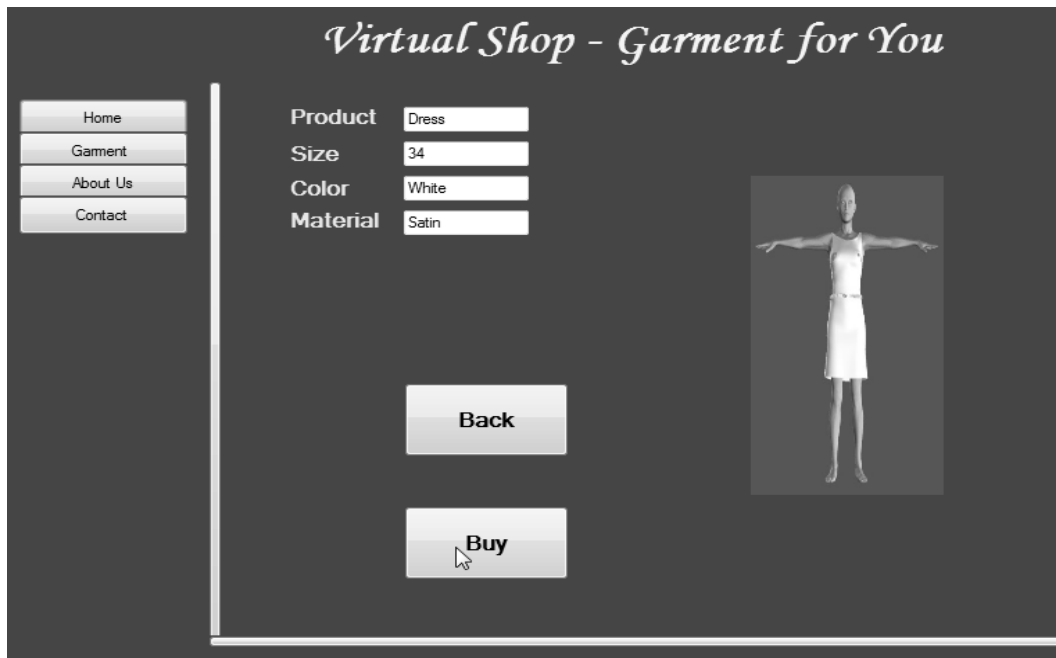


Figure 5: Garment simulation around the parametric mannequin¹

The customer can choose to see 2D view of the garment product or to see 3D view— where he can rotate the dressed mannequin. The clients don't have access to the product or body database. The customer can only choose the product type, size, textile material and to upload the body scan or to use a parameterized body that exists for sizes. The client can proceed to buy the product if this is in accordance with his needs (figure 6).



Figure 6: Purchase procedure

3. E-SHOP - SELLERS SIDE PRESENTATION

The manufacturers and sellers are addressing to a class of unknown buyers. Because of this, the challenge is to predict how the buyer could look like and what its body size may be. For that the e-shop has a body classification² depending on some important body dimensions. This classification is based on population composed of 50 bodies. This work proposes a body classification depending on sizes from bust, waist and hip area³ (1).

$$C = f(P) \quad (1)$$
$$P \in \{P_1, P_2, P_3\},$$

Where :

P = body scanned parameters;

P₁ = bust girth;

P₂ = waist girth;

P₃ = hip girth;

The sellers have access to textile material, body and size databases and can modify all of these. For customers these information are encapsulated to facilitate a good operation of the shop, for security reasons. On the server side a comparison is made between the body uploaded by the client and the bodies from morph type database⁴ (figure 7). For creating the morph type database a clustering algorithm⁴ was used. Some information contact about clients is stored in the database, morph type corresponding name and preferred or purchased products.

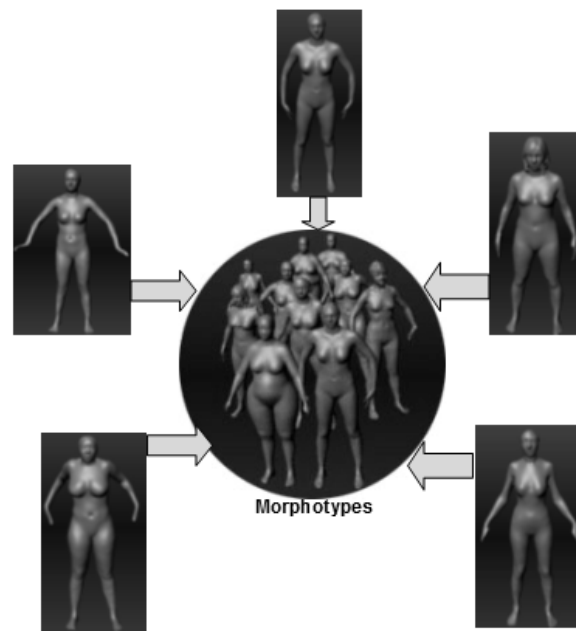


Figure 7: Morph type database

4. CONCLUSIONS

The strengths points of the e-shop are:

- Time-saving;
- Fast simulation on the wearer's body;
- 24 of the 24-hour accessibility;
- Shopping action is simple, convenient;
- In short time hundreds of requests can be processed;
- Possibility to sell anywhere in the world;
- Fast feedback from customers;
- High percentage of customer satisfaction.

The advantages of using the 3D body scan file are that this file collects more information about the costumer's body and the fit garment probability is very good. The garment virtual trying is simpler and saves time.

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STUDY ON THE INFLUENCE OF INK QUANTITY ON COLOUR INTENSITY IN INK-JET PRINTING

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Keywords: Color intensity, Pre-coating, CIELab, Spectroscan, Ink-jet inks.

Abstract: *This paper presents the influence that the ink quantity has over the color intensity obtained in natural silk inkjet printing with reactive inks. The quantity of ink used in ink-jet printing is adjusted by changing the resolution, drop size and the number of steps. To see if there is a linear behaviour of the dependence of color intensity depending on the ink quantity, the printing is made by 20 %, 40%, 60%, 80%, 100%. The behavior of the four primary colors (CMYK) from ink-jet printing was analyzed. The results obtained were listed in the table and then graphically represented. It was also determined by the color difference ΔE_{ext} between the result with the highest yield and the remaining samples.*

1. INTRODUCTION

If in the conventional printing the quantity of the printing paste deposited on the surface of the screen opening, in the ink-jet printing the quantity of ink deposited on the fabric depends on the drop size, number of steps, resolution etc. In this chapter the measurement results on the intensity of colours printed in 2 and 4 steps with small, medium and large drops are presented.

2. PROCEDURE

For the tests silk samples with the size of 40x30cm were used. The silk has a weight of 50 gr/m². The silk samples were treated by the following formulation:

- Thermacol MP 200gr/l
- Urea 100gr/l
- Na₂CO₃ 20gr/l
- Lyoprint RG 20gr/l
- Lyoprint AP 10gr/l
- Water up to 1 L.

Treatment was done on the HVF-350 padder produced by Mathis AG, treating speed 1m/min and pressure of 3 atm. With this pressure, a squeezing degree of 80%⁴ was provided. Drying of the treated fabric was done with an IR dryer, LTE model produced by Mathis AG, at a temperature of 60°C for 1 min and 30 seconds. After treatment, the material is printed with Viper TX8165 printer produced by Mutoh. The RIP Program used is TexPrint v.13.0.1.3514.

Samples were printed with the following settings:

- Resolution 720dpi;
- Smooth Diffusion;
- 4pass;2pass
- Small, medium, big Dot Size;
- Uni-directional;
- Ink limit 400;
- With no colour profile.

The Ink-jet ink used is from the Novacron MI range produced by Huntsman based on reactive dyes. After printing, ink sets for 15 minutes at 102°C⁵ and 80% humidity in DHE steamer produced by Mathis. Setting. Figure 1



Figure 1. Sample steam setting

After setting, the fabric is washed as follows:

- Cold water rinsing for 2 min;
- Soaping at 40 °C with soaping solution concentration 2g/l for 3 min;
- Soaping at 80 °C with soaping solution concentration 2g/l for 3 min;
- Soaping at 80 °C with soaping solution concentration 2g/l for 5 min;
- Rinsing at 80 °C for 3 min;
- Cold water rinsing for 2 min;
- Squeezing 400 rot/min

on a washing machine HC60 model produced by IPSO.

After washing the fabric is dried at 80 ° C for 1 min and 30 seconds in IR dryer LTE model produced by Mathis AG. Reading Lab color value is done in space SpectroScan produced by GretagMacbeth. Figure 2 is used for recording the results ColorPort v.1.5.4 software produced by X-rite. Measurement data were tabled and then plotted for better interpretation and observation of the color differences.

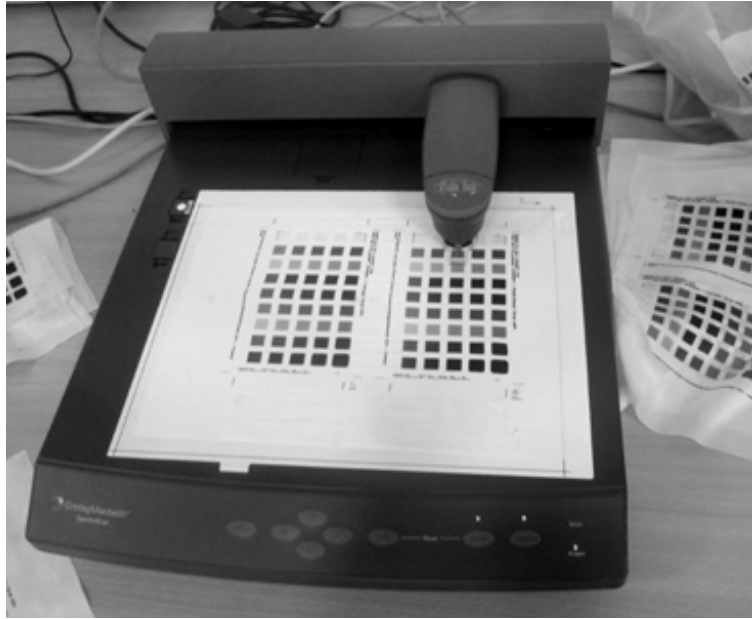


Figure 2. Value reading with Lab SpectroScan.

3. RESULTS

The results obtained from the readings of printed samples in 2 steps and 4 steps have been graphically represented. In order to represent bidimensionally, the Lab values were firstly represented in La and then in Lb.

3.1 Colour difference between printing in 4 steps and printing in two steps with small drops (5,4 pl)

Cyan

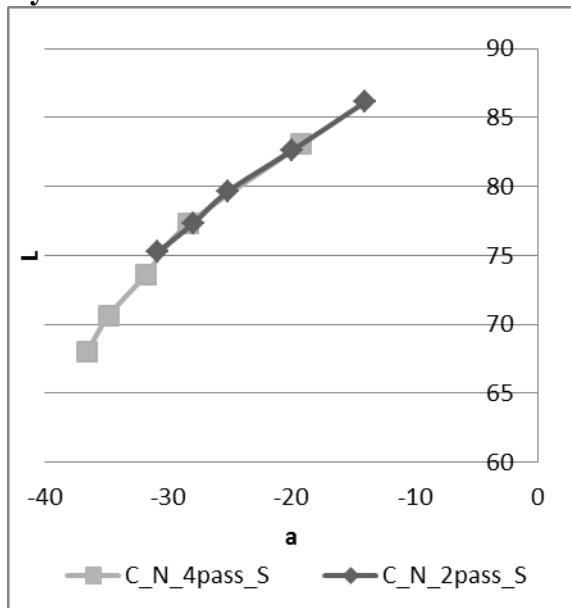


Diagram 1. Difference between 4 steps and 2 steps La Lb

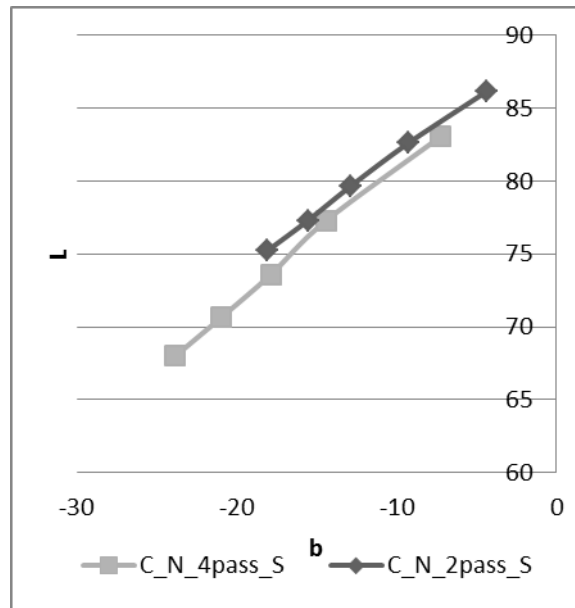


Diagram 2. Difference between 4 steps and 2 steps

The diagrams show that in small drop printing in 4 steps more saturated and darker colors are obtained and in printing in 2 steps lighter colors are obtained. This can be explained by the double quantity of ink applied to the fabric in four steps printing. Noteworthy is the linear behavior of color intensity compared to the quantity of ink used.

Magenta

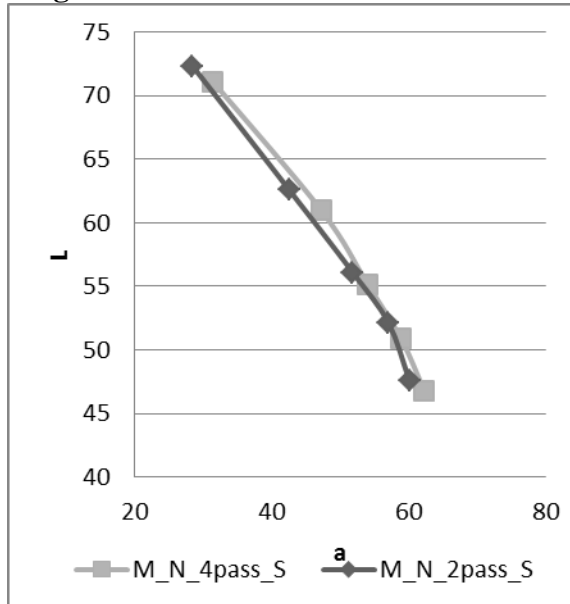


Diagram 3. Difference between 4 steps and 2 steps La

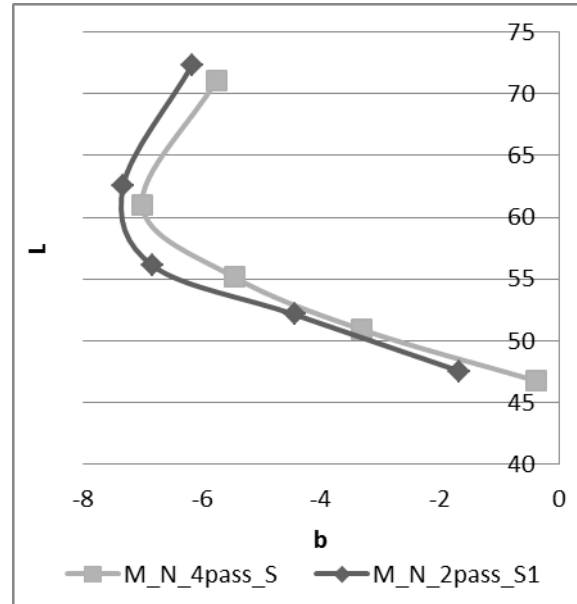


Diagram 4. Difference between 4 steps and 2 steps Lb

When printing with the magenta there is an equality in behavior, the double ink quantity not affecting the colors obtained. Up to 20% nonlinear behavior of the color obtained in relation to the quantity of ink used is shown in diagram Lb.

Yellow

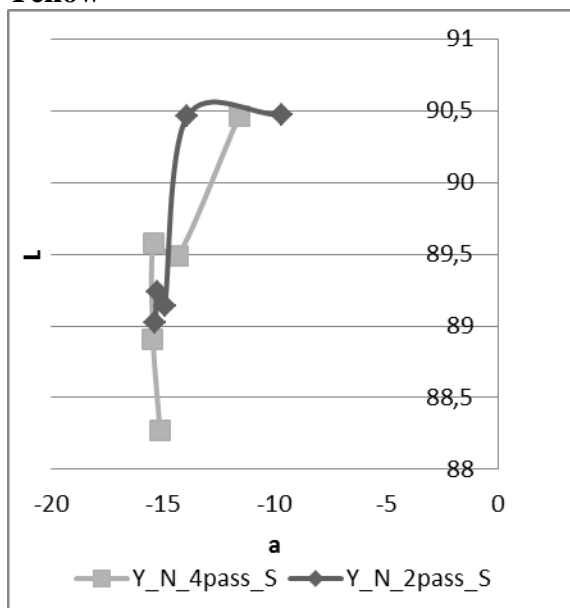


Diagram 5. Difference between 4 steps and 2 steps La

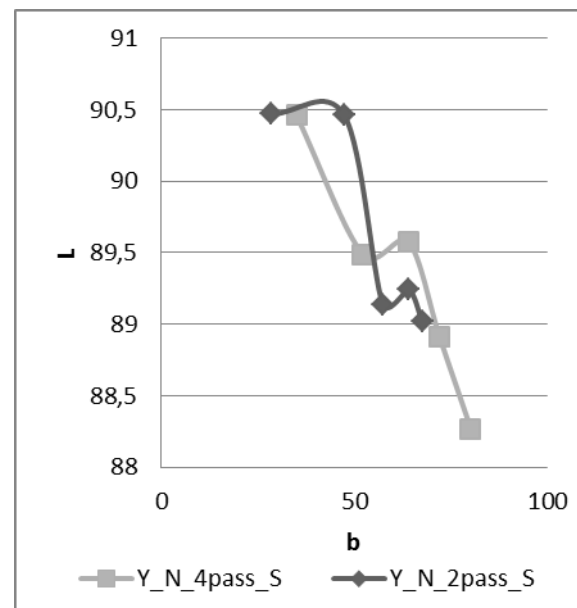


Diagram 6. Difference between 4 steps and 2 steps Lb

When printing with yellow in two steps there is no difference in brightness between printing by 20% and printing by 40%, but only in intensity. When printing in 4 steps more saturated colors are obtained.

Black

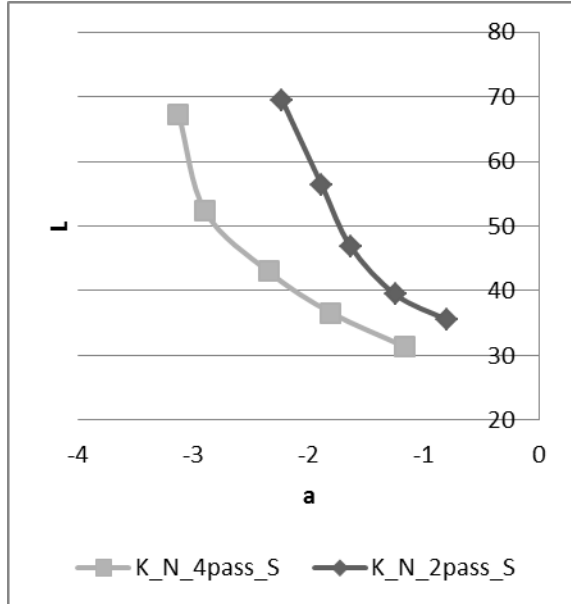


Diagram 7. Difference between 4 steps and 2 steps La

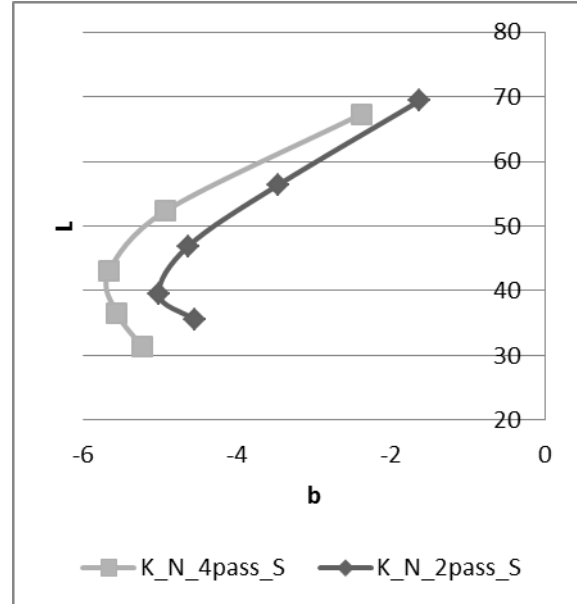


Diagram 8. Difference between 4 steps and 2 steps Lb

A widening of the color area in 4 steps printing with Black MI-2000 reactive ink can be seen. A positive thing is also the linear behavior of the ratio ink quantity/ color intensity.

3.2 Colour difference between printing in 4 steps and printing in two steps with medium drops (11,5 pl)

Cyan

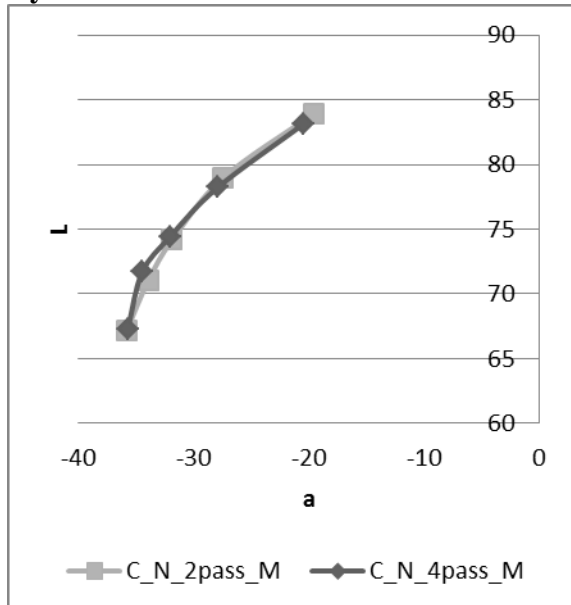


Diagram 9. Difference between 4 steps and 2 steps La

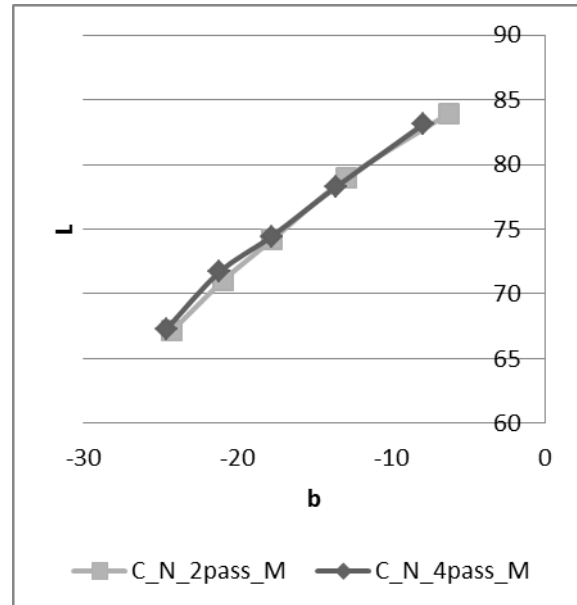


Diagram 10. Difference between 4 steps and 2 steps Lb

In printing with Cyan medium drops, no colour intensity increase can be seen.

Magenta

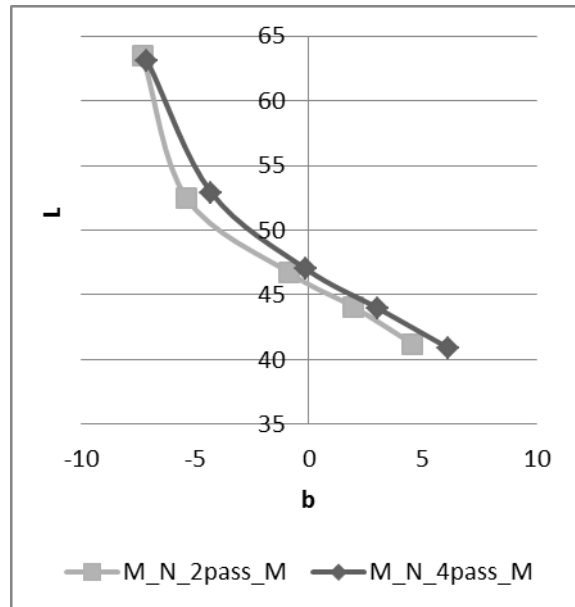
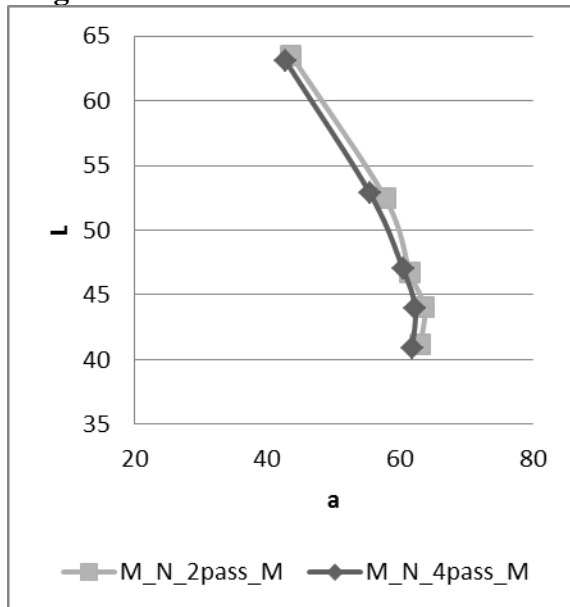


Diagram 11. Difference between 4 steps and 2 steps La Diagram 12. Difference between 4 steps and 2 steps Lb

and in printing with Magenta medium drops there is no difference between 2 and 4 steps.

Yellow

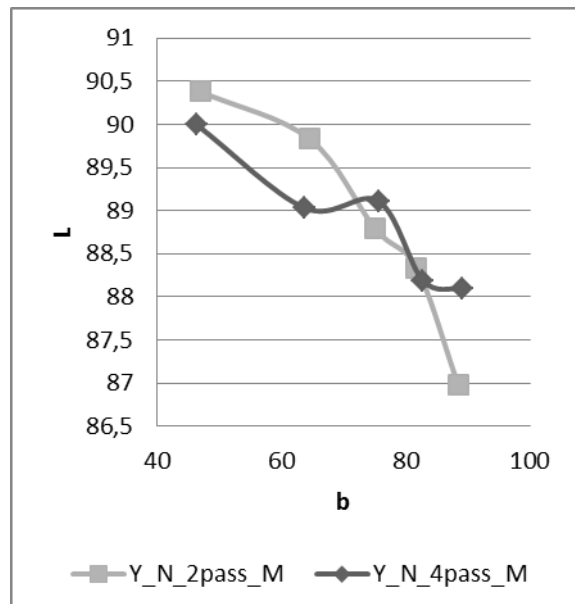
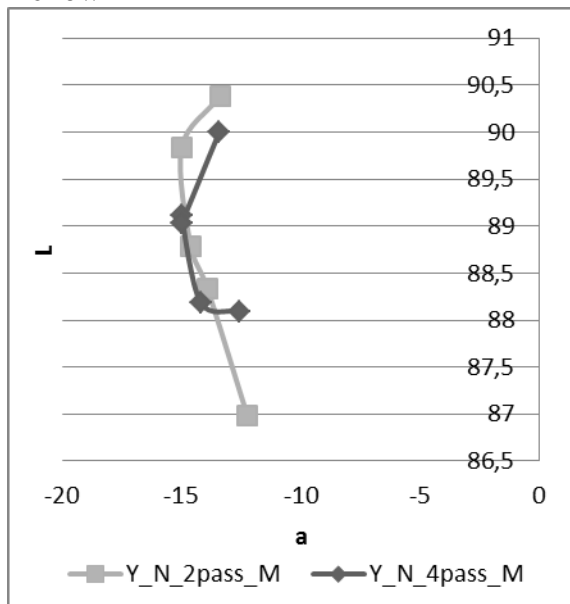


Diagram 13. Difference between 4 steps and 2 steps La Diagram 14. Difference between 4 steps and 2 steps Lb

From both diagrams an abnormal behavior can be seen, with double quantity of ink less intense colours being obtained. The diagram Lb shows that in 2 steps printing a linear dependence of the colour intensity on the quantity of ink used is seen.

Black

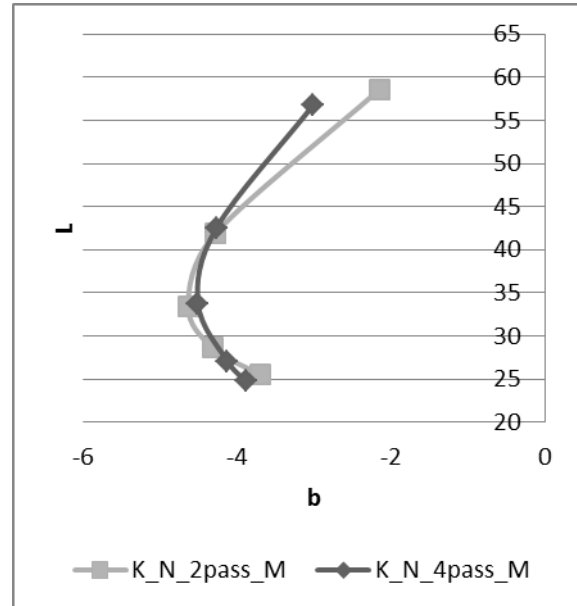
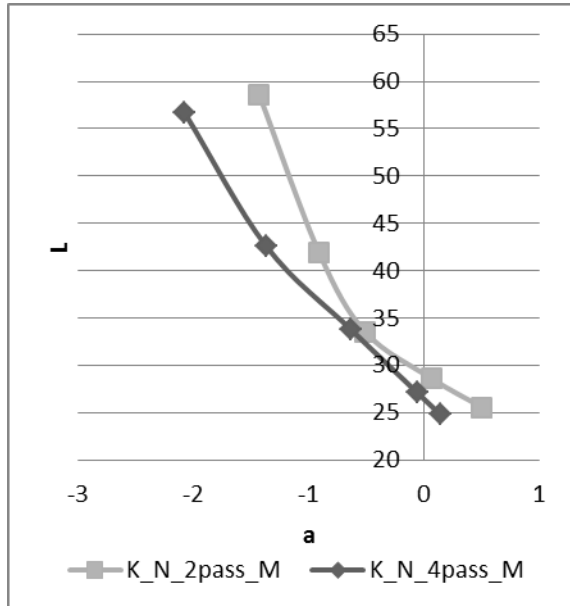


Diagram 15. Difference between 4 steps and 2 steps La Diagram 16. Difference between 4 steps and 2 steps Lb

In printing samples with Novacron MI-2000 Blackin in four steps, darker and more saturated colors are obtained. Double quantity of ink has effect only in printing with up to 60%.

3.3 Colour difference between printing in 4 steps and printing in two steps with large drops (25 pl)

Yellow

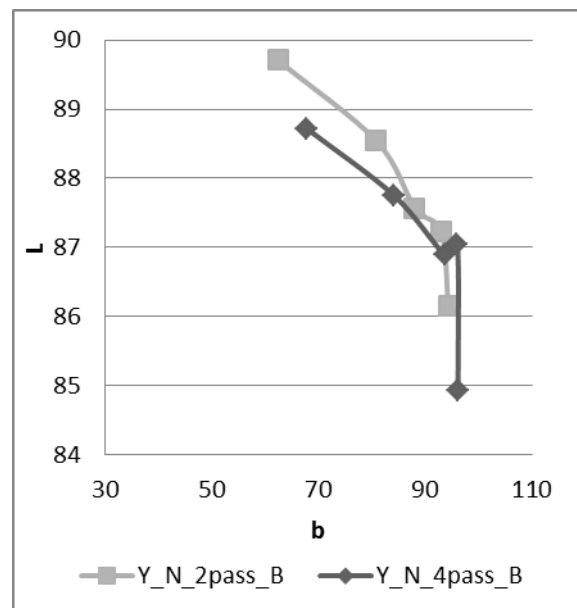
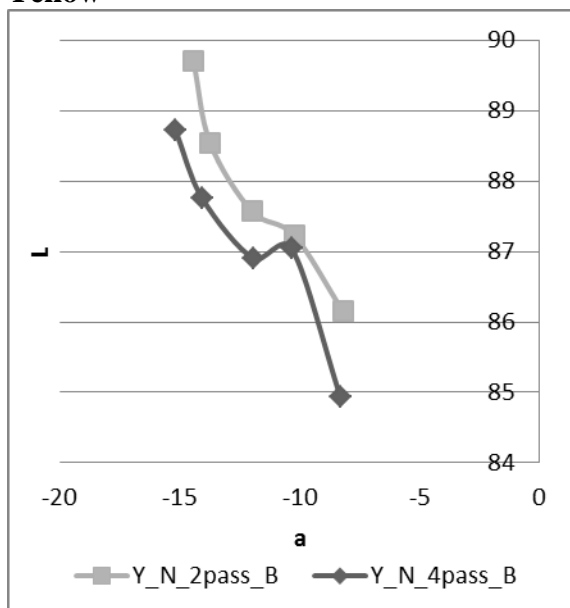


Diagram 17. Difference between 4 steps and 2 steps La Diagram 18. Difference between 4 steps and 2 steps Lb

When printing with large drops of yellow color, there is a difference between printing in 4 with steps and printing in 2 steps. The diagram shows that printing in 4 steps shows darker and less intense colours. On the other hand, there is a loss of light colors.

Cyan

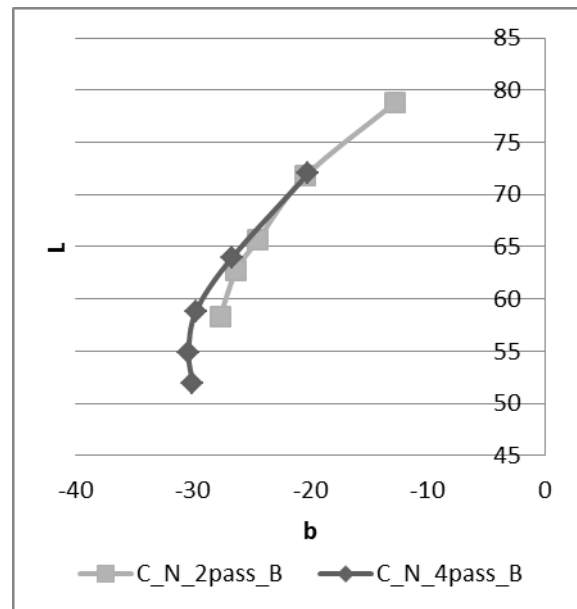
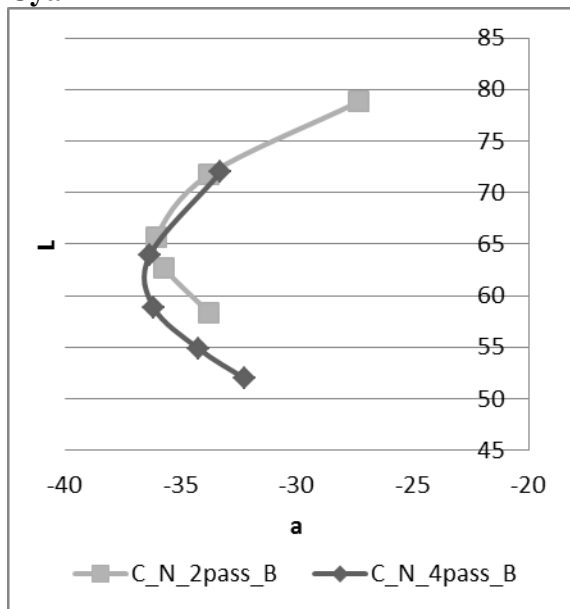


Diagram 19. Difference between 4 steps and 2 steps La Diagram 19. Difference between 4 steps and 2 steps Lb

Position and shape of the curves in the diagrams show that darker colors are obtained when printing in 4 steps steps, but there is a loss of light colors. The fact that more intense colors are not obtained can be due to the limitation of the natural silk printing with reactive inks.

Magenta

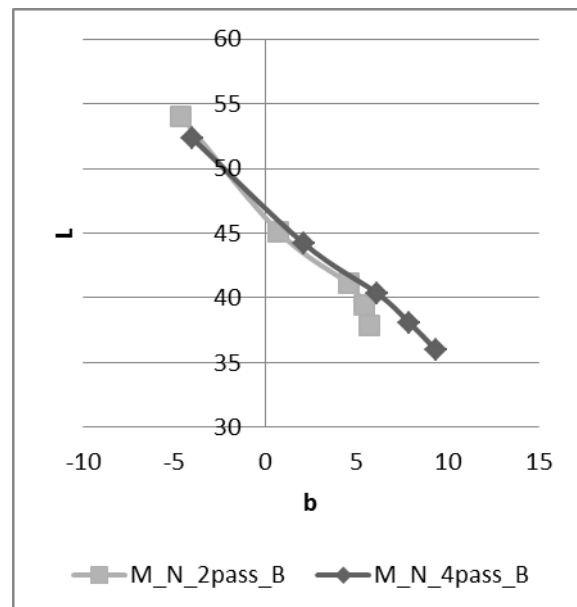
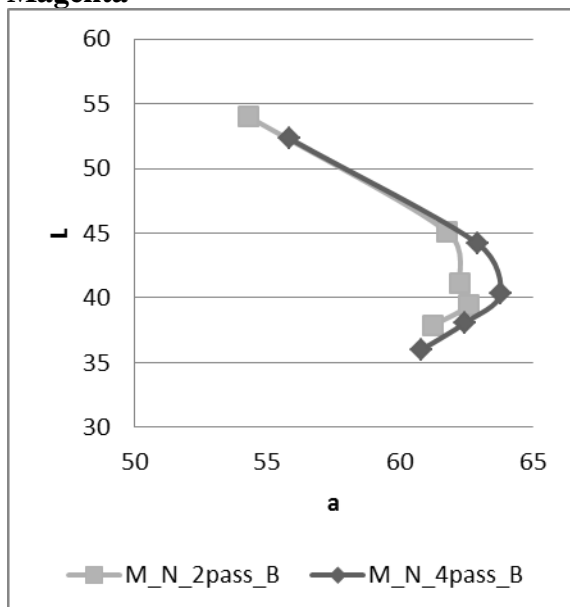


Diagram 21. Difference between 4 steps and 2 steps La Diagram 22. Difference between 4 steps and 2 steps Lb

Lb diagram shows that by increasing the quantity of ink, darker and more intense colours are obtained. Note the linear shape of the curve.

Black

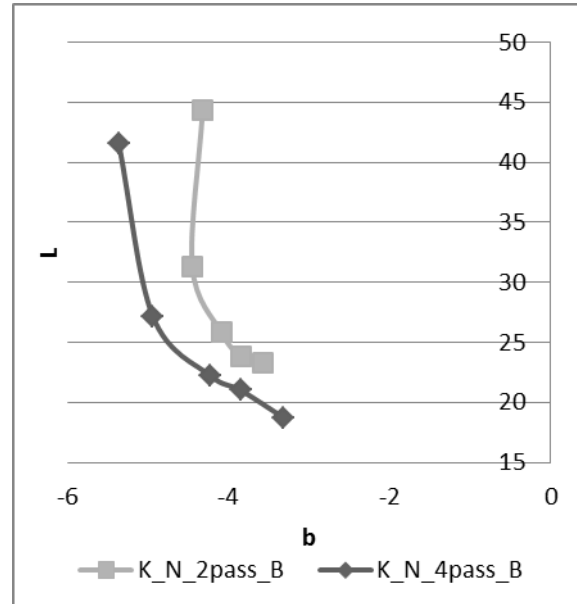
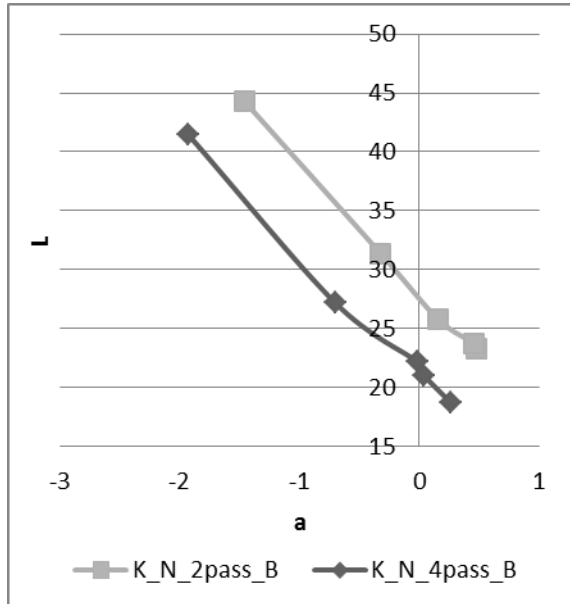


Diagram 23. Difference between 4 steps and 2 steps La Lb

Diagram 24. Difference between 4 steps and 2 steps Lb

In Black printing in four steps, the diagram La shows an increase in intensity throughout the interval, and t Lb shows a shade of blue, which makes black to seem more intense.

4. CONCLUSION

The graphical analysis shows that there is a greater difference between the two colors in printing in 2 or 4 steps if the printing is done with small and large drops. The same thing is seen in the case of printing in 4 steps where more intense or darker colors are not obtained if double quantity of ink is used. Printing in 4 steps is done in a time which is almost doubled. That is why the best ratio of production cost / color is obtained by printing with large drops in 2 steps.

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ENVIRONMENTAL AND SOCIOECONOMIC SUSTAINABILITY THROUGH TEXTILE RECYCLING

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Keywords: sustainable development, recycling, closed loop SCM modeling, textiles waste

Abstract: *The recycling of waste materials is directly associated with the concept of sustainability. This paper examines the process of achieving environmental sustainability through recycling of textile wastes. It is organized as a review and editorial article, relating relevant research regarding sustainable development and recycling of textile waste, and outlining economical, environmental and social implications and suggested futures actions. The recycling of textile waste can serve as a mean of providing solutions to financial, environmental and social problems such as high cost of waste disposal, and diminution of natural resources, create workplaces, opened opportunities for SMEs. The benefits and problems of this exercise are also highlighted. The conclusion drawn is that the recycling of waste brings benefits to all three aspects that define sustainability: economical, social and environmental, especially in solving the numerous ecological problems and boosting new economy sectors, but there are also negative aspects, too. To quantify potential ecological benefits, economical and social effects of textiles waste recycling, the paper proposes modeling framework which makes tradeoff between costs of reverse network for textiles waste establishment and operation, and its effects on the land use reduction, employment increase, and resold wearable textiles earnings. The main limit of the presented model is the fact that it is based on the premise that there is already a collecting infrastructure and a market for the recycled products. But, in Romania the textile waste collection, especially the post-consumer one still remains an unsolved problem. As a conclusion, the paper presents several proposals and their solutions represent future research directions.*

1. INTRODUCTION

In the past few years sustainable development has become a widespread constituent part of economic and environmental policy not only in developed country but also in many developing countries. Today's most burning environmental problems arise from ever increasing volumes of worldwide production and consumption and the associated material flows¹. The supply of goods is always correlated to the use of natural resources, including raw materials (renewable and non-renewable), energy, water and land. The processes of accelerated population growth and urbanization are expressed by a greater volume of waste generated².

The literature review revealed a large gap in terms of Life Cycle Assessments (LCAs) conducted over the end-of-life of textiles. Some LCAs studies deal with the assessment of the

environmental impacts of clothing^{3,4,5} or other type of textile products like carpets⁶ or furniture⁷ but little highlights was placed on potential benefits from recycling. The economists' and environmentalists' studies on technical^{8,9} and economic¹⁰ requirement for sustainability revealed the need for increasing waste prevention and recycling.

2. TEXTILE RECYCLING

Textile industry is not only one of the most important consumer goods industries but it also has an essential impact on the environment. Because it is a diverse and heterogeneous industry which covers an important number of activities from the transformation of fibres into yarns and fabrics to the production of a wide variety of products such as hi-tech synthetic yarns, wool, bed-linen, industrial filters, geo-textiles, clothing it generate varied significant adverse environmental and social impact across it global lifecycle.

Textile waste is not a large waste stream by weight or volume but has a significant environmental impact connected to the production of textiles. The clothing and textile industry accounts for an estimated 5 to 10% of all environmental impacts throughout the EU, so improving the environmental performance of the industry is vital.¹¹ Estimates of the global warming potential of textile productions are 16.9 kg CO₂-equivalents per kg of 50% cotton and 50% polyester or 25 kg CO₂-equivalents per kg of textiles¹² and the general carbon dioxide saving of textile recycling are 1-1.5 kg of CO₂-eq. per kg textiles¹³. Therefore, compared to most other wastes the global warming potential from production of textiles can be considered rather high per unit weight.

Directive 2008/98/EC defines recycling as a *recovery operation by which waste materials are reprocessed into products, materials or substances*. Similar textile recycling refers to the processing of fibres back to make new products. However, in this paper recycling is defined as a method of reprocessing used clothing, fibrous material and clothing scraps from the manufacturing process. A fairly large amount of textiles is recycled into wipers or used as filling material but the actual processing of recovered textile into new products is still relatively minor¹⁴. Textile reuse as second-hand clothes is also sometimes considered as a form of textile recycling while there is no reprocessing. The reusing or recycling of textile waste is not only an important means of solving the several environmental problems but also a means of socioeconomic and environmental sustainability. Reusing slows the consumption process and the need for costly and energy consumptive production of new products¹⁵.

2.1. Sources of Textile Waste

The use and application of textiles is widespread. Apart from the clothing, there are other numerous applications where textile fabrics can be found e.g. in furniture, home wares, transportation, medicine etc. Textile waste originates from two main streams: industries/institutions and population. Industrial textile waste is generated from commercial and industrial textile applications including commercial waste from properties such as carpets, drawer, curtains, hospital refuse or other industrial applications. Collection and chemical contamination issues make this category as the least likely to be recycled so an important share of these goods is sent to landfill or incineration. However, there is research currently being undertaken by a number of industries to utilize this resource¹⁶.

According to the Council for Textile Recycling, textile recycling material can be classified as pre – or post consumer waste. Pre-consumer waste is arising during the manufacture of a product and post-consumer waste is “*any type of garment or household article made from manufactured textiles that the owner no longer needs and decides to discard*”.

During the processing of textile products, large quantities of pre-consumer fibrous waste can be generated in the form of fiber and yarn, off-cuts, selvages, sheerings and rejected materials. During their production, 50% of the fibers are wasted¹⁷.

Post-consumer textile waste consists of any type of garments or household article, made of some manufactured textile that the owner no longer needs and decides to throw away. The characteristics of fast fashion have driven the consumption of new clothes to increase by 60% in the past decade¹³. Several researchers who studied reasons for clothing disposal revealed that most respondents kept items as long as they were wearable and said that they stopped wearing cheap clothing for three main reasons: lower quality, new fashion trend or clothes were bought for one specific occasion.¹⁸ Another recent study from the UK exposed that the respondents discarded clothing mainly due to the condition of clothing, new trends in fashion, lack of space, loss of emotional attachment and changes in body shape.¹⁹ As a result, textile waste is directly influenced by the state of the economy and has become the fastest growing sector of household waste.²⁰

2.2. Textile recycling process

In the following paragraphs the advantages and issues that might come up during the entire recycling process, according to figure 1 will be presented.

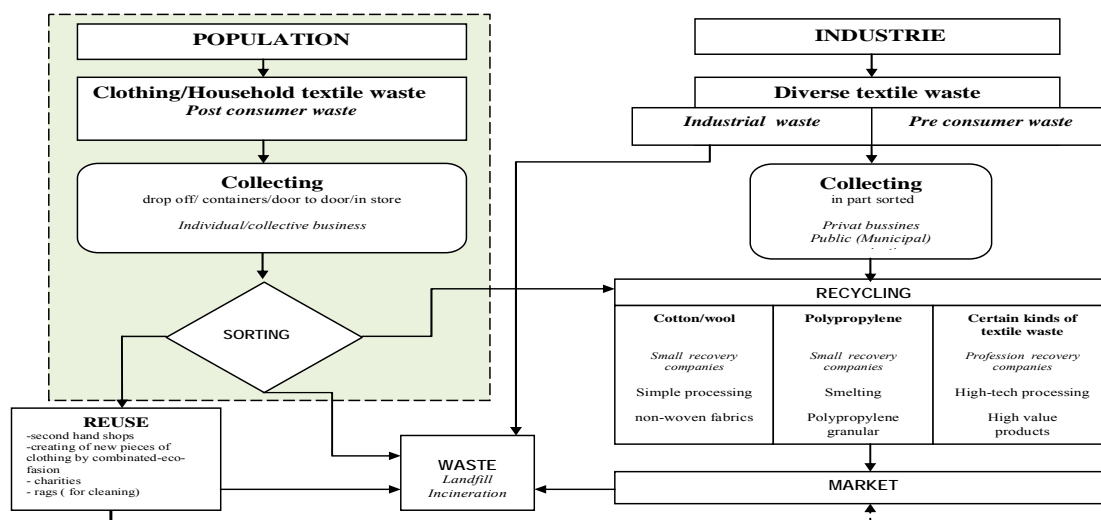


Figure 1. Textile Recycling Process

In the first stage the discarded textiles are collected and processed, where they are sorted, cleaned and made ready for recycling or manufacturing new products.

The environmental aspects of the waste stage of clothing or other household article depend on the method of disposal. Clothing is disposed of in two ways: through separate collection or, more typically, with the domestic waste and end up in municipal landfills or are burnt.

Separate collection leads to reuse, like second-hand or recycling as cloth, yarn, or even as fiber. A study of the disposal of clothing among 40-year-old women in Norway shows that all the women in the study disposed of clothing they had never use and about 18 % of all registered garments that had never been used or only used once or twice.²¹

A number of different systems have been implemented to collect material to be recycled from the general waste stream. These systems tend to lie along the spectrum of trade-off between public convenience and government simplicity and expense. The main categories of textile collection are through drop-off centres, curbside collection, door to door collections and, newest, in store collection. Drop-off centres require the waste producer to carry the

material to a central location, either an installed or mobile collection station or the reprocessing plant itself. They are the easiest type of collection to establish, but suffer from low and irregular throughput. The door to door collection method of garments is a successful method and is being prevalent in poor land from a long time.

The recycling or usage of textile waste for new product manufacturing is connected to certain requirements for the waste. When considering textile recycling we must identify the material it is made of. Various wastes are classified into detailed groupings according to their materials, colors, and average piece size. The contents of textile waste are very complex including products manufactured from a unique type of fiber or from a combination of several fibers. Cărpuş et al. provide a comprehensive classification of the categories of textile waste by origin, fiber composition, size, color etc.²² The textile's composition will affect its durability, method of recycling and, of course the costs, too. Complex mixtures of fibers make separation more difficult and more costly, and this has implications for the profitability of textile recycling. Generally, textile waste recycling has low profit margins with an average profit rate lower than 0.01 USD per kg waste recycling, so that many recyclable textile wastes were treated as municipal solid waste.²³ However, this situation is changing with the market entry of several professional recovery enterprises utilizing advanced technologies to produce high valued-added products. Conversion of this type of textile waste into useful materials, serves a dual function: elimination of waste, and introduction of new products such as recycled fibers, recycled clothes, toys, carpets and filling material, especially from cotton fiber.

All collected textiles are sorted and graded by experienced workers, who are able to recognize the large variety of fiber types resulting from the introduction of synthetics and blended fiber fabrics that make the process more costly, and this has implications for the profitability of textile recycling. There is a trend of moving these facilities from developed countries to developing countries either for charity or sold at a cheaper price.

The second stage involves the manufacturing of new products from the raw material obtained by the processing of the old products. Recycling technologies, existing for textile too, are divided into primary, secondary, tertiary, and quaternary approaches. Primary approaches involve recycling a product into its original form. Secondary recycling involves processing a used product into a new type of product that has a different level of physical and/or chemical properties. Tertiary recycling involves processes, such as pyrolysis and hydrolysis, which convert the waste into basic chemicals or fuels. Quaternary recycling refers to waste-to energy conversion through incineration. Studies have indicated that many forms of fibers recovered from various waste streams are suitable for concrete reinforcement.

There are two major ways of recycling pre-consumer textile materials; mechanically, where fibres are pulled apart and reworked into yarn, and chemically where fibres are repolymerized into a chemical and spun. For many recycling processes such as nylon depolymerization and polymer resin recovery, it is required or mandatory to sort the feedstock according to the type of face fibers. The most fiber types can be identified true a simple melt point indicator or, more effective with infrared and Raman spectroscopy.²⁴

Knitted or woven woollens and similar materials are "pulled" into a fibrous state for reuse by the textile industry in low-grade applications, such as car insulation or seat stuffing. The textiles are shredded and mix together with other selected fibres, depending on the intended end use of the recycled yarn. The blended mixture is carded to clean and mix the fibres and spun ready for weaving or knitting. The fibres can also be compressed for mattress production. Textiles sent to the flocking industry are shredded to make filling material for car insulation, roofing felts, loudspeaker cones, panel linings and furniture padding.

Regarding the industrial waste, especially carpet recycling, in the last years a broad based

research agenda has been carried out at the Georgia Institute of Technology in collaboration with the industry²⁵. These studies include depolymerization, melt processing, material component separation, composite material and reinforcement for concrete and soil. There is a relatively new trend towards the use of textile waste in the building construction field such as roofing material²⁶ and brick from textile waste sludge²⁷.

Finally, the process ends with the purchasing of recycled goods by the consumers at the top of reverse supply chain (production plants) and completes the recycling loop.

The non recyclable products or those that are collected together in municipal waste ends up in landfills or are incinerated. Public concerns exist for the incineration of polymer waste. The main negative environmental impact of the incineration is the emission of greenhouse gases. A positive effect of burning waste is the production of energy. However, with advanced technologies and proper management, waste-to-energy conversion can be a viable alternative to landfill. Textile waste in landfill contributes to the formation of leachate as it decomposes, which has the potential to contaminate groundwater. Another product of decomposition in landfill is methane gas, which is a major cause of greenhouse gases significantly contributing to global warming (as compared with carbon dioxide, it has a high global warming potential of 25 for a time period of 100 years).²⁸ The decomposition of organic fibers and yarn such as wool produces large amounts of ammonia as well as methane. Cellulose-based synthetics decay at a faster rate than chemical-based synthetics. Synthetic chemical fibers can prolong the adverse effects of both leachate and gas production due to the length of time it takes for them to decay²⁹.

3. MODELING FRAMEWORK FOR THE TEXTILES WASTE RECYCLING EFFECTS ESTIMATION

The life cycle of a product can be either a closed loop or an open loop. Closed loop products move from raw materials to design and production to packaging and distribution to use and maintenance, and are then recycled with materials and components being captured and entering back into the system. In an open loop system, products are incinerated or disposed of at the end of their useful life. In order to quantify potential ecological and social benefits and economical effects of textiles waste recycling this paper proposes the LP optimization model of the closed loop supply chain network, shown in Figure 2.

Model is based on the assumption of an existing forward supply chain, operating on a market with known supply and demand, and reverse network that should be established. Hence, the purpose here is to analyze modelling approach that could be used to establish three level reverse logistics network for textile waste, composed of a set of collection points, sorting points and recycling facilities, while respecting its impact on the land use reduction, employment increase, and resold wearable textiles income, versus reverse network for textiles waste establishing and operating.

Most of the literature about reverse logistics network design considers various facility location models based on the MILP, and in many cases forward and reverse networks are modelled separately. Consequently, this leads to significant problem reduction, which is the case with this paper. However, there are only few researches related to problems in textiles recycling networks³⁰. A remarkable chapter about carpet recycling explores the issues of reverse logistics for recycling within the carpet industry, including an economic analysis of the success of carpet recycling³¹. Unlike carpet, which is usually transported to collection facilities by contractors, collection of post-consumer apparel may necessitate pick-ups of small volumes from a high number of locations, like apparel drop-off locations or curbside pick-ups. The transportation cost of this type of collection is significant higher as compared

to full truck loading. To minimize total transportation and fixed costs, a collector has to identify the optimal number and location of local and regional collection facilities.

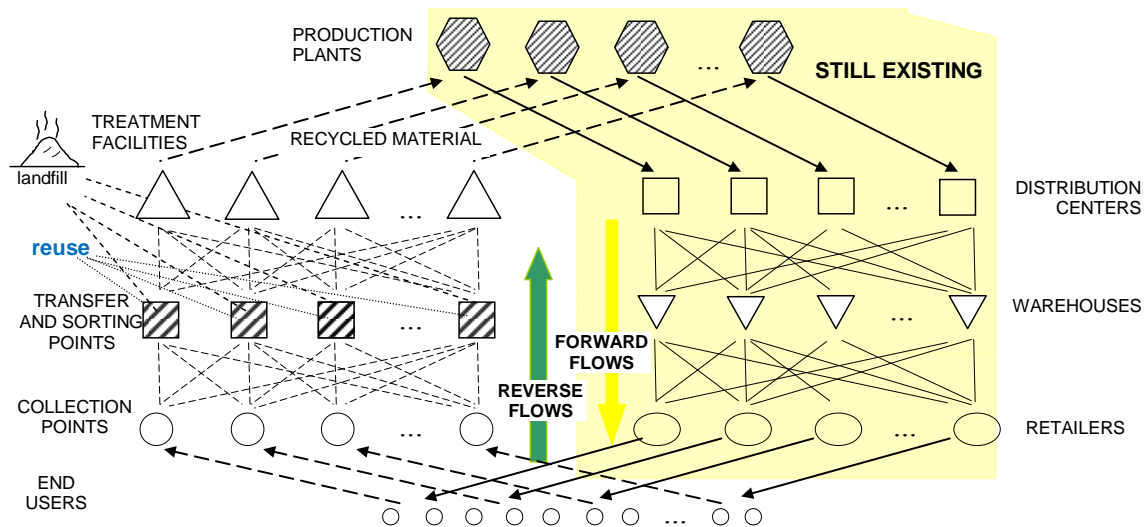


Figure 2. Textiles closed loop supply chain network

Mainly, facility location model proposed here is similar to the formulation of two-stage capacitated facility location problem (TSCFLP) described in Klose and Drexl³² but because of multilevel problem nature, different network structure and different objectives, mentioned approach has modified. In the proposed model formulation following notation has been used³³:

i end user/owner of textile products (aggregated in larger units like buildings, schools,...)

k collection point (drop – off location) which receives textile waste products from users

l sorting facility which receives textile waste from collection points

j recycling facility which receives sorted textiles waste from sorting facilities

$C_{kb}, C_{lj}, C_{lj+1}, C_{lj+2}, C_{js}$ - costs of transporting textiles waste from collection point k to sorting facility l , respective from sorting facility l to recycling facility j , from sorting facility l to second hand shop, from sorting facility l to the landfill site, from recycling facility j to production plant s

$X_{ik}, X_{kl}, X_{lj}, X_{lj+1}, X_{lj+2}, X_{js}$ - fraction of textile waste from user i collected at collection point k respective from collection point k transported to sorting facility l , from sorting facility l transported to recycling facility j , from sorting facility l transported to second hand shop, from sorting facility l transported to the landfill site and from recycling facility j to production plant s .

G_k, G_l, G_j, G_s capacities of collection k , sorting l , recycling j , and production facility, resp.

f_k, f_l, f_j costs of opening collection, sorting and recycling facilities at locations k, l, j respectively (including financial equivalent of land use)

Y_k, Y_l, Y_j binary variables, equals 1 when collection, sorting or recycling sites are opened, otherwise equals 0

α fraction of wearable textile waste that can be resold and directly reuse $0 \leq \alpha \leq 1$

β fraction of sorted textile waste that will be land filled $0 \leq \beta \leq 1$

λ earnings from resoling unit quantity of textile waste that can be directly reused

ρ -financial equivalent of employment increase per unit quantity of recycled textiles

Proposed multilevel MIP model of reverse logistics network for textile waste, composed of a set of collection points, sorting and recycling facilities, which respects sustainability criterions is presented below.

Minimize :

$$\sum_k \sum_l C_{kl} X_{kl} + \sum_l \sum_j C_{lj} X_{lj} + \sum_l (C_{lj+1} X_{lj+1} + C_{lj+2} X_{lj+2}) + \sum_j \sum_s C_{js} X_{js} + \sum_k f_k Y_k + \sum_l f_l Y_l + \sum_j f_j Y_j - \lambda \sum_l X_{lj+1} - \rho (\sum_k \sum_l X_{kl} + \sum_l \sum_j X_{lj}) \quad \text{s.t.} \quad (1)$$

$$\sum_k X_{ik} = q_i \quad \forall i \quad (2)$$

$$\sum_i X_{ik} - \sum_l X_{kl} = 0 \quad \forall k, \sum_k X_{kl} - (1 - \alpha - \beta) \sum_j X_{lj} - X_{lj+1} - X_{lj+2} = 0 \quad \forall l \quad (3)$$

$$\sum_l X_{lj} - \sum_s X_{js} = 0 \quad \forall j \quad (4)$$

$$X_{ik} \leq Y_k G_k \quad \forall i, k, X_{kl} \leq Y_l G_l \quad \forall k, l, X_{lj} \leq Y_j G_j \quad \forall l, j \quad (4)$$

$$\sum_i X_{ik} \leq G_k \quad \forall k, \sum_k X_{kl} \leq G_l \quad \forall l, \sum_l X_{lj} \leq G_j, \forall j, \sum_j X_{js} \leq G_s \quad \forall s \quad (5)$$

$$Y_k \in (0,1), Y_l \in (0,1), Y_j \in (0,1), X_{ik}, X_{kl}, X_{lj}, X_{lj+1}, X_{lj+2}, X_{js} \geq 0 \quad (6)$$

The objective function (1) minimizes the sum of reverse network for textiles recycling costs, and its effects on the virgin materials consumption, land use reduction, employment increase, and earnings from wearable textiles. Note that because objective function should be minimized, positive effects of network establishing are included as negative values that are subtracted from costs. All the supply of textile waste available at the users site is defined by constraint set (2). Equalities set (3), represent flow conservation constraints. Constraints sets (4) prohibit units from being routed through collection, sorting and recycling sites unless the site is opened. Constraint set (5) limit the quantities sent to the collection, sorting, recycling and production sites up to the capacity of those sites. Constraint sets (6) enforce the domain of decision variables.

4. Stage of Textile Recycle Waste in Romania

There are numerous economic, social, technological, environmental and institutional barriers to implement textile recycling in Romania. The main textile waste sources in Romania are similar with the other European countries: industry and population.

In the last period, due to the expansion of the garment sector and decline of the fibers and woven production, in Romania, the main part of all pre-consumer waste consists of textile material cuttings. These are cuttings of a different size with dyeing defects, stained, knitted fabric cuts up to 2 kg of weight, fine knitted fabric waste, woven fabric borders, weighted cuttings of woven fabrics (0.1-2 m length), cutouts from garment sewing industry.

Across Europe, an estimated 15 to 20% of potential existing tonnage is really collected. Germany and the UK on the one hand, and Poland and Romania on the other hand are a few exceptions³⁴. Germany and the UK have an ecological tradition and collect roughly 70% of its potential, while Poland and Romania are importers of textiles from western countries. However, no specific evidence has been founded regarding of the amount of the imports of unsorted used clothes. It is not clear how much from this are resold, in second-hand shops, or are ending in the landfill. The number of second hand shops or the tonnage of textile they processed is also unknown. Without greater transparency in the industry, it is difficult to determine the size of this segment.

Unfortunately, while sustainability requires a long term outlook, both private- and public-sector leaders are focused on short-term results. Therefore the main method of waste disposal in Romania is landfill. The EU waste directive from 2008 (2008/98/EC) presents a structure for preferred treatment of waste, where landfill (or other means of disposal) is the least

preferable option and waste prevention is the most preferable option.³⁵ The energy content of the waste materials may be recovered, at least partially, by burning the waste materials³⁶. Incineration of waste is not a wide spread practice in the country. Currently there are only 7 incineration centers (Alesd, Campulung, Bicaz, Deva, Fieni, Hoghiz and Medgidia).

A further problem is the lack of recycling technologies in Romania. Regarding the green technologies, a roadmap for 2010-2013 was developed in order to implement the Environmental Technologies Action Plan (ETAP Romania). Romania was granted transition periods to achieve conformity with the EU directives for municipal waste sites by 2017. By 2013, it is anticipated to achieve a degree of recovery of useful material from packaging waste through recycling or incineration for energy generation of 60% for paper and cardboard, 22.5% for plastics, 60% for glass, 50% for metals and 15% for wood. Special measures are envisaged, with completion deadlines between the end of 2008 and 2013, for the recovery of discarded electrical and electronic appliances and for the closure of underperforming medical waste incineration plants³⁷, textile wastes are not treated separately, they are included in "other waste".

5. CONCLUSIONS

There are benefits to all three aspects that define sustainability: **economical** (recycling programs cost fewer than waste disposal programs), **social** (creating of new jobs, new opportunities for small/family business, build communities around environmental issue) and **environmental** (conserves natural resources, saves energy, prevents the destruction of natural habitats). There are also negative aspects, too. One of the problems is that the used textile imported (especially second hand clothes) by poor or developing countries can lead to an economic decline in that sector.

The most important barriers to recycling are the lack of infrastructure, equipment and technology, the lack of material to recycle and the lack of consumer awareness. The amount of textiles for recycling in a region is too small for an efficient recycling. Therefore recycling must be done either abroad or partly with imported textiles.

Governments, as well as businesses and individual consumers, each play an important role in making the recycling process a success. Government intervention may mean that new value-added recycling technologies enter the market, and therefore the average system will change. If recycling technologies improved, then recycling could be as or even more worthwhile than reuse, particularly if the systems become closed loop. Recycling of textiles presents several promising technologies and ideas for recycling systems. It is useful to settle on the far-off prospects of material use for an environmentally sustainable economy. The motivation for waste and pollution prevention through recycling can only be fully appreciated when related to long-run goal of material conservation.

The current inadequate situation regarding waste management in Romania is a challenge for change. This can be brought under control by focused efforts and by a participation of all interested factors in the Integrated Waste Management Plan, which was approved even in 2004 and completed in 2007.

Effects of textile recycling on sustainable development is modelled as MIP model with the objective of analyzing trade off between costs of reverse network for textiles waste and its effects on the virgin materials consumption, land use reduction, employment increase, and earnings from wearable textiles. Model application and adjusting is left for the future research.

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TECHNOLOGY AND SYSTEM FOR SILK COCOONS SPINNING

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Keywords: Spinning, silk cocoons, sericine, filament, silk worms

Abstract: *Spinning represents a multitude of operations which represent a technological process, so that from the fibers placed in the flow the textile yarn with the adequate characteristics shall be finally obtained. The structure of the silky sheath comprises three layers of filaments, but only the middle one can be spun. The yarn fineness is given by the number of component filaments. The quality classification of raw silk yarns is made by uniformity and fineness, and subsequently by: strength, elasticity, color. The obtaining of raw silk filament yarns include: the boiling of cocoons, the removal of wastes from the outer layers of silk cocoons and the finding of fibre ends, spinning and reel winding. The integrated system for spinning cocoons provides these operations. The boiling of cocoons in water with a certain hardness, alkalinity and temperature ensures optimum conditions for spinning: permeability of silky wall, softening of sericine, which cements the fibres into the cocoon. The main components of this aggregate are: the frame with boiling vat, heatset heating and boiling installation and filling and emptying installation. Boiling is done in a heatset vat made of stainless steel which is in conformity with the technology imposed. The boiled cocoons are stored in other vat with controlled temperature until the beginning of the spinning operation. Finding bifilament fiber ends is done with a brush with oscillatory motion. The removal of the first layer is done manually until the spinnable filament layer. The searching of bifilament fibre ends and their union in a number corresponding to the thickness of the yarn to be produced is done by the spinner who operates the machine. As the bifilament of a cocoon is too thin to be used in the textile industry, it is necessary to gather more filaments of many cocoons. The system is electrically powered and has two workstations.*

1. INTRODUCTION

Natural silk is one of the oldest textile fibers, with a high ecological level, being an absorbent elastic natural fiber, having neutral pH and representing static electricity.

Natural silk, as well as the products derived from it have applicability currently not only within the textile field, the silk thread being also used in electronics, aeronautics and surgery.

The sericulture in Romania has a tradition of over 500 years, silk being known as floss silk, a thread used in manufacturing the traditional headkerchiefs, embroidered peasant blouses, scarves and other pieces of popular traditional clothing.

Sericulture had a strong decline in Romania after 1990, this situation being generated by

the rooting out of large surfaces of mulberry trees as a consequence of land retrocession. Out of the approximately 5,000 hectares with intensive plantations of small mulberry trees in 1989, only 150 hectares currently exist. The liquidation of 19 processing companies out of 20 existing in 1991, the lack of regional centres for the distribution of silkworms eggs and the collection of silk cocoons have been the main factors for the downturn of this field. The forecast for the year 2010 indicates the production at a level of 20 tones for the silk cocoons.

The downturn of the silk production has not been a phenomenon specific for Romania, but for the global level starting with the year 1995, because of the law demand on the global market. The preoccupations within this field in Romania currently target the preservation of the genetic patrimony and the reproduction of the biological material.

Approximately 93% of the global silk exports currently come from China, whereas Brazil, the second exporting country, holds only 5% of the global market. In the past, among the main producers of raw silk in Europe, there were Italy, France and Bulgaria.

As regards the oldest times until the modern days, the basis for raw textile materials has been made out of natural fibers only, such as wool, cotton, linen, hemp and others.

Out of these spinnable fibres, there have been obtained, initially through traditional spinning and later on through industrial spinning, using adequate equipment, threads made out of fibres having relatively small lengths.

Spinning represents a complex of operations part of a technologic process during which, out of the fibres introduced within the flow, the textile thread with the imposed characteristics is finally obtained.

The basic parameter, that influences the processing of the textile fibres within the process of spinning, is the length of the fibers. According to their length, the textile fibers are divided in fibers having determined lengths (long fibres, medium fibers and short fibers) and filament fibers.

A different textile raw material produced under a filament form has been found in nature that does not need real spinning, namely natural silk. Characterised by high finesse, good mechanical resistance and a special brightness, this raw material with very fine filaments and which is particularly long is part of natural protein fiber series. The silk, together with the products derived from it, have applicability currently not only within the textile field but the silk thread is also used in electronics, aeronautics and medicine-surgery.

By the particular specificity of the filaments, the operations of making a continuous succession with parallel threads convertible into thread are eliminated.

The uniformity of the resulted thread, made out of several bifilament fibers, is an essential condition for its quality.

Natural silk represents around 0.15 – 0.17 % of the total textile fibers used at a global level.

The physical-mechanical and chemical properties of silk give it a particular role within the textile industry, maintaining it a luxury product that cannot be easily matched.

2. THE PROPERTIES OF SILK FIBRES¹

Tear strength. From the point of view of its mechanical characteristics, natural silk is one of the strongest natural textile fibers, its specific strength being of up to 68 da N/ mm².

The tear strength of a natural silk thread is higher than that of a steel thread, with the same diameter.

The tear strength is of 3.9 – 4.5 g/dener, 0.34-0.39 N/tex, respectively. When using the tear strength criterion, natural silk places first, as compared to other natural fibers. One silk

thread with a diameter of 1mm can bear a load of 40- 42 kg, a cotton thread with the same thickness will break under a load of 18kg, while a wool thread can take up to 15 kg.

A 1m long natural silk filament can bear a load of 4 to 13g.

The strength of natural silk is influenced by the presence of sericin (silk gum), and it decreases a lot after degumming (the partial removal of silk gum) and can reach up to 30 % of its initial value.

Humidity also influences the strength of the silk fiber, its strength decreasing by 10 – 15 % when wet.

The mechanical properties of de-gummed fibers depend on the treatment temperature.

Wear resistance. The wear resistance of a fabric represents the usage time of that fabric. Generally, textiles made of natural silk can be used for a longer period of time.

It can be said that the wear resistance of natural silk is comparable to its tear strength.

Silk elongation. The elongation of a textile fiber consists of its increase in length under the influence of an axial force, and it is defined as the ratio between the length increase and the initial length of the fiber, percentage wise.

In reality, this property is equivalent to the tear elongation, which is a little lower than that of the wool fiber.

When dry, the tear elongation reaches up to 20-25 %, and when wet it reaches 30 %.

Natural silk can be deformed by elongation, up to 20%, without breaking, but in order for it to come back to its initial size, i.e. to display its elasticity, this elongation must not exceed 2% of its initial length.

Natural silk has a remarkable elastic recovery capacity, which is also displayed in silk fabrics.

If a natural silk fabric is pressed or deformed, it will go back to its initial shape and position very quickly after it is released.

3. THE USE OF NATURAL SILK

Its exceptional properties, unique in their own way, such as delicacy, elasticity, softness, handle, drape, easy dying and others play an important role in the demand of natural silo textiles.

After the discovery of silk and the creation of natural silk fabrics, a wide range of uses came up, starting with luxury items, paintings, paintings on silk, clothes for emperors and noblemen, up to the making of items for technical uses.

Crepe de Chine is a fabric used to make dresses.

Crepe satin is a shiny fabric on one side and mate on the other side, used for the production of evening gowns.

Taffeta is a flat fabric, with a characteristic shine, used for the production of blouses, dresses and linings.

Atlas is a fabric used for manufacturing corsets, coat linings, dresses, etc.

The **brocades** are heavy fabrics with drawings and shiny metallic effects, sometimes made of gold. They are used for ball gowns, special clothes, theater wardrobes, furniture fabrics, velvets.

Knits are used for manufacturing scarves, women's underwear, blouses etc.

Fabrics for clothes, rain coats, umbrellas, bathing suits, decorative fabrics. Such fabrics are rendered water-repellent and water-proof.

Out of the silk items manufactured in the past, one can mention harnesses, such as bridles, reins and others.

Some of the important recent technical articles made of silk are:

- bolt fabrics for flour mills, especially with the purpose of obtaining pastry flour; these fabrics have also been used for manufacturing fans.

- screens for protection against insects, as well as for stencils used for textile printing. These stencils have been replaced nowadays by synthetic silk fabrics.

- parachute fabrics, characterized by their remarkable strength. Nowadays, they are made of polyamide.

As it is a poor conductor of electricity, it is used for dressing electricity conductors, flanges.

The balloons used for observing the weather are dressed in natural silk.

Another practical feature – surgical non-absorbent sutures are made of the silk gum glands of the silkworm.

The use of silk in human medicine. Japanese researchers have created a genetically modified variety of the silkworm which produces collagen that can be used to bandage wounds or for producing artificial human tegument.

A natural silk used to manufacture artificial skin has been discovered in China, at the Senjang university. Thanks to the capacity of artificial skin to regenerate, a 3cm diameter wound is healed in 20 days.

British researchers have obtained a natural silk which helps nerve cells regenerate, grow and fixate on silk threads. The silk, which is called Spidrex, helps with the recovery of nerve cells in the spinal cord in case it is damaged.

4. OBTAINING RAW SILK FIBERS

The qualitative and quantitative reception of viable dry cocoons is done according to the inspection and analysis methods stipulated by the standards.

Several steps need to be taken by small and medium sized companies during the technological process of obtaining raw silk fibers, such as:

- the inspection and storage of cocoons;
- the preparation of the cocoons for spinning;
- boiling of the cocoons for spinning purposes;
- graining of the cocoons;
- obtaining the raw silk filament yarns;
- the storage of the raw silk threads (hanks).

Obtaining the raw silk filament yarns includes the following operations: boiling the cocoons, removing the harsh layer and finding the ends of the fibers, spinning and rolling them onto the reel.

- The purpose of boiling the cocoons is to ensure the best spinning conditions, respectively to render the silk wall waterproof, the softening of the sericin, cementing the fibers in the cocoon and partially destroying the cohesion forces between the two filaments of the fiber.

In order to unwind the fiber off a dry cocoon, a pulling force of 13cN is required, and off a cocoon soaked in warm water, 7cN. In order to unwind the fiber off a cocoon in good conditions, it is required that the pulling force reaches values comprised between 1.5 and 3cN.

Boiling the cocoons is done in a set of containers with different spinning environment temperatures.

The silk cocoons are placed in a mobile container, with a removable lid. The container is perforated, in order for it to be flooded when placed in one of the boiling containers.

The mobile container filled with cocoons is placed in the first container for approx. 1

minute, in 60⁰ - 65⁰C warm water, then the mobile container filled with cocoons is transferred into the second container in 90⁰ -- 95⁰C hot water, for another minute, and afterwards, the mobile container is placed once again in the first container for one minute. After these operations are over, the mobile container filled with cocoons is transferred into the second container with 90⁰ -- 95⁰C hot water for 3 – 10 minutes. The cocoons boiled in this way are stored in the container with 60⁰ - 65⁰C hot water until they pass through the graining device and until the fiber ends are tied together.

The values of these parameters depend on the breed of the silkworm that made the cocoon, on the caliber of the cocoons, on the thickness of the silk layer.

Boiling the cocoons ensures the production of uniform silk fibers from the point of view of their structure.

- Removing the harsh layer and finding the ends of the fiber.

During this phase, the cocoons are still being boiled in the 60⁰C hot water container, the ends of the fibers need to be found and tied, and the parts that cannot be spun are eliminated.

Finding the end of the bi-filament fibers and tying them together to form a thread with the right thickness is done by the operator working with the device.

Rubbing the cocoons with a brush is an operation that must be done with great care, because putting a lot of cocoons together creates a bundle which is very hard to unwind, increasing the quantity of sweepings.

The cocoons are pushed under the brush.

The brush makes a semi-rotating movement around the axle.

This movement ensures the rubbing of the cocoons floating in the hot water container until the first layer of silk, respectively the harsh layer starts to come off and the ends of the fibers undo. By rubbing, the cocoons stick to each other, forming clusters.

Shaking is done through a pick-up move, and this movement makes the cluster of cocoons shake until they fall back in the water, after the ends of the fibers are caught.

The cocoons for which the ends of the fibers have not been caught go back under the brush and are rubbed once again. Taking off the harsh layer by hand is not allowed, since it can unwind into a silk layer which is too thick, and will become waste.

- spinning of the cocoons and putting the thread on the reel.

Pulling the bi-filament thread off the cocoons is the main operation.

In order to obtain the raw silk thread, it is necessary for the fibers of several cocoons to come together, depending on the delicacy of the thread that must be obtained.

5. SPINNING SYSTEM OF THE SILK COCOONS

The manufacture of the silk spinning machine has been made based on the documentation elaborated in INCDTP.

The machine consists of two different modules which can function together or individually:

- the installation for boiling and storage of the boiled silk cocoons (Figure 1);
- the installation for the friction of the cocoons and for the capture of the fiber ends (Figure 5);
- the installation for the spinning of the natural silk filaments from the cocoons (Figure 6)

5.1. INSTALLATION FOR THE BOILING AND STORAGE OF THE BOILED SILK COCOONS (Figure 1)

It is a single casting metallic construction formed of a body and two boiling tubs. The electrical and the hydraulic installations are being mounted on the body. They are necessary for the adequate enfoldment of the silk cocoons in view of spinning.



Figure 1: Installation for the boiling and storage of the boiled silk cocoons

The tubs have electrical resistances and the temperatures sensors with an adjustment range of 40-100⁰C are located at a distance of approximately 5 cm from the heating resistance.

The electrical resistances are protected by a separator made of a perforated plate (Figure 2) on which the perforated baskets are placed (Figure 3). The silk cocoons are going to be boiled inside them.

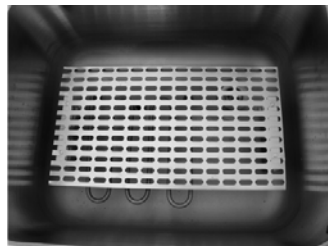


Figure 2



Figure 3

Each tub is equipped with a used water delivery pipe.

The electrical installation comprises: resistive type heating elements; pressure sensor; thermal regulator.



Figure 4

The pressure sensor with a $P_{\max.} = 1\text{Bar}$ and $U_{\max} = 250\text{ V}_{\text{AC}}$ maintains the pressure from the installation at the same level, within the limits established when adjusted and it fulfills the following functions:

- protects the resistances from heating;
- maintains a constant level of water in the tub;

The universal type temperature regulator has a large number of options as regards the input and output levels.

It allows 18 types of selectable probes including power transformer inputs, relay outputs or unified signal 0-10 V, 4-20mA.

The protection degree of the electric panel (Figure 4) is IP 65. It ensures the following types of protection:

- protection against the access to the powered components with an access probe with a diameter of 1 mm;
- the penetration of dust in quantities that may influence operations and safety;
- protection against the projected water (the water which is projected from all directions must not have negative effects).

The elements located on the front panel (appliances, buttons, warning lights) of the electric panel have an increased protection level (IP 54).

The temperature level is accomplished with a temperature regulator with a digital display.

In order to ensure an adequate work environment, the installation of an exhaust hood for the released steam has been provided.

5.2. INSTALLATION FOR THE FRICTION OF THE SILK COCOONS AND FOR THE CAPTURE OF THE FIBER ENDS (Figure 5)

Within this operation the silk cocoons continue to be boiled, the fiber ends are searched for and caught and the inadequate segments are eliminated.

The boiled silk cocoons are placed into the installation tub with the water at 60°C , where with the help of a brush they are scrubbed in order for the exterior layer to come off and to catch the filament ends.

For the removal of the first layer the brush executes an oscillation movement.



Figure 5 Installation for the friction of the silk cocoons

The installation consists of a metallic body on which a stainless steel container is mounted, the mobile teasel and stir ensemble and the electrical installation. Inside the container there is a thermostat electrical resistance which ensures the level of temperature imposed by the technological process.

The installation has a mobile lever (which can be vertically folded) on which the teasel brush is mounted. This brush is controlled with the help of a 24 V_{cc} electric motor and it may function in both rotational directions.

The change in rotation direction is ensured by the electrical supply of the motor through an electronic device.

The mobile lever can be vertically folded at an angle of 120°. This movement possibility also ensures the stir of the cocoons which under the action of their own weight fall inside the container and the ends of the fiber remains between the teeth of the brush.

The operator has the possibility to collect the number of fibers necessary for the spinning.

Through the technological operations carried out on this installation the first layer of unused filaments is being removed and the ends of the fibers that are going to be used during the spinning process are caught.

5.3. INSTALLATION FOR THE SPINNING OF THE NATURAL SILK COCOONS (Figure 6)

The installation is provided with two spinning stations. It is a semi dismountable metallic construction on which the following elements are placed: the spinning container, the device used to add new filaments, rolls for the determination of the thread trace, reeler, depositor (thread conductor), hydraulic installation, steam generator, container used for the maintenance of the humidity level, thread control device, electrical and automation installation.



Figure 6 Installation for the spinning of the natural silk cocoons

The container is a single casting metallic construction made of a rectangular pipe on which the spinning container is installed (Figure 7), being equipped with an exhaust pipe installation.



Figure 7

Inside the container there is an electrical resistance with a large built up surface area which ensures an adequate thermal efficiency and a Pt 100 type temperature sensor.

In order to avoid burning of the thermal fuse, the installation has been equipped with a pressure sensor (with operates in steps) for the detection of water inside the installation. This

pressure sensor doesn't allow for the resistance to be power supplied if water is not present inside the container.

The universal type temperature regulator has a large number of options as regards the input and output levels. It has a digital display installed in the electric panel.

The filament adding device (Figure 8) mounted on the body is operated with the help of an electric motor with a 24 Vcc reduction.

On the shaft of the motor there is a splined conducting wheel which sends the movement through a splined belt to the two filament adding disks.

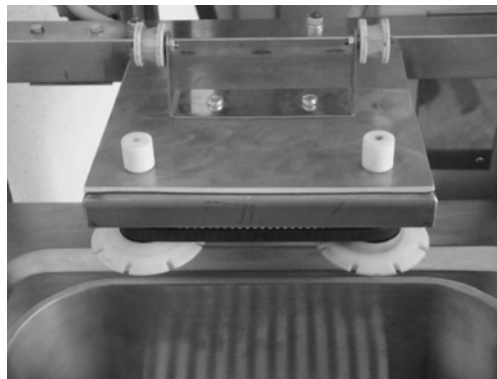


Figure 8

For energy saving reasons, this device operates only when new filaments must be added. Its bringing into operation is achieved through an operator pedal.

The guiding rolls (Figure 9) define the route of the silk thread (Figure 10) until its reeled on a reeler. They are equipped with cross bars made of glass tubes which decrease the adherence of the fibers to the rolls.

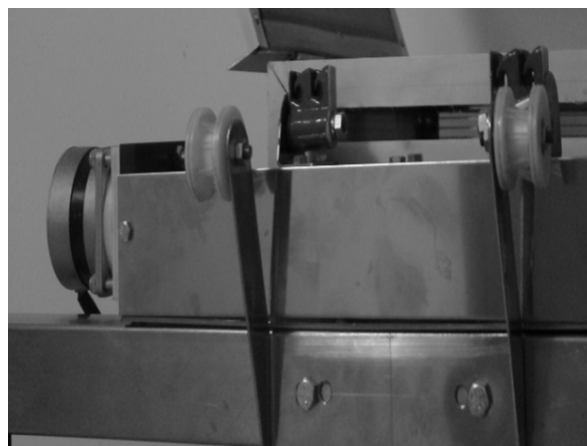


Figure 9

The position² of the rolls forms a quadrangle which ensures the self cleaning of the spun thread of the silk gum and water surplus.

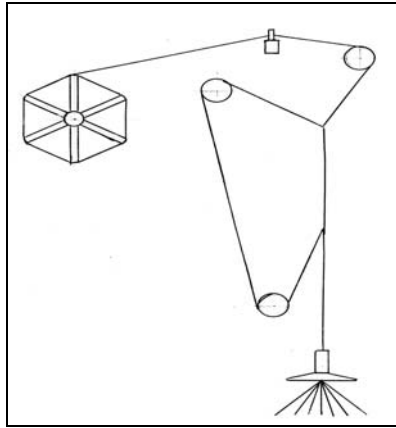


Figure 10

A thread presence sensor mounted before the last guiding roll signal through a green/red display the presence or absence of the thread. In case of the thread's absence the motor of the reeler will stop working.

The steam generator (Figure 11) equipped with a timer ensures the maintenance of the humidity inside the container where the reeler operates.

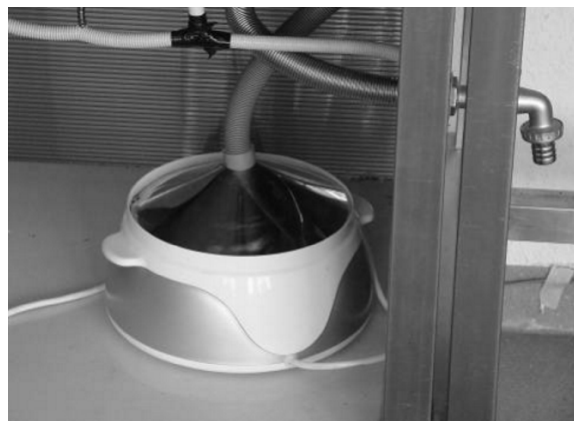


Figure 11

The reeler ensures a circular line of 670 mm and it is operated by a splined belt with the help of a pair of splined wheels and of a 24 Vcc DC electrical motor with a reduction.

The depositor (Figure 12) ensures the cross arrangement of the threads of the reeler. This is made through the rotation movement of the reeler together with the translation movement of the depositor.

This device is synchronized with the deposit speed of the threads on the reeler, but it can also function independently. The device consists of: a driving group operated by a “steper” type motor, a mobile frame which transforms the rotation movement into a linear-translation movement (which ensures the transport of the “thread” guidance elements) and a mobile sensor system (blockers) which limit the depositing area.



Figure 12

The translation movement is made through the circulation of a cart equipped with two conducting thread components on two columns and an operational rod with a trapezoidal thread operated by a “stepper” motor. The cart lift is adjustable within the limits of 40 - 70 mm.

The control system of the execution elements ensures the protection and the load coupling to the supply circuit.

The heating resistances are connected to the power supply through an electric contactor.

The protection of the supply circuit is ensured with the help of a thermal magnetic circuit breaker.

In case of mono-phased circuits the protection is ensured through a uni-polar thermal magnetic circuit breaker.

6. CONCLUSIONS

The specific qualities of the silk make this raw material much requested especially in the fashion industry, but also in other related domains, such as medicine, electrotechnics, aerospace, etc.

The activity connected to silk worm raising influences positively the level of living of the rural population, by being an activity which can be performed together with the daily activities.

This activity can be performed within the family, or organized in small enterprises.

The necessary investment to establish a sericultural farm rise up to 14-15,000 EURO, the profit margin being about 15-18% starting the third year from the time of the set up.

Setting up a farm requires:

- airy and not humid room
- at least 2 ha of land cultivated with mulberry trees (on one ha of land we can plant 8,000 mulberry tree seedlings).

In order to raise silk worms, out of a 10 gram-can of eggs a 30 square meter space is needed.

One hectare of mulberry tree plantation is enough to raise the silk worms from 100 grams of eggs/ series.

The raising period is between the months of May-August and two series of silk worms can be raised.

Out of one gram of eggs approximately 2 kilograms of silk cocoons can be obtained, and for raising of one gram of eggs of silk worms we need 35-40 kilograms of mulberry tree

leaves.

The food of silk worm can offer natural protection in dry places if it is applied as a protection curtain against wind and sand drifted by the wind.

Pupas can raise the income of silk worm raisers if used as food for animals.

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DYEING OF CLONED SHEEP WOOLS USING DRIED LEAVES OF WALNUT, MINT AND SAGE

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Abstract: *Natural dyestuffs had been commonly used for dyeing of leather and textiles since prehistoric times. Use of natural dyestuffs started to lose its popularity right after invention of synthetic fibres. Natural dyestuffs are classified in two groups, animal and vegetable based dyestuffs. Vegetable originated dyestuffs are derived and extracted from fruits, roots, leaves, barks, and/or seeds of plants. Animal originated dyestuffs are derived from the whole body of some insects. Nowadays natural dyestuffs are not preferred in vast production as it is for synthetic dyes. However increased awareness of environmental issues in recent years has positive influences on the use of natural dyestuffs. Some consumers are intentionally prefers natural dye used textile items even though their low degree of colour fastness properties and high prices. There have been many different researches about natural dyeing processes using mordant. In this study dried leaves of walnut, mint and sage have been used for wool dyeing. Wool fibres that have been used in this work are special fibres that are cut from cloned twin sheep in Veterinary Faculty of Istanbul University, Turkey. Different types of mordant are used as pre treatment and post treatment of naturally dyed wool fibres. Therefore three groups of dyed fibres are prepared as non mordant fibres, pretreated mordant dyed fibres and post treated mordant dyed fibres. Influence of mordant type on the colour of dyed fibres, colour efficiency of fiber types, and rubbing, washing, and light fastness degrees of specimens are evaluated. Among the cloned sheep fibres, there are not any difference has been observed in terms of fastness values and colour efficiency.*

1. INTRODUCTION

Natural dyes have started to be used in the organic textile products recently. Increasing environmental awareness, fashion trends and environmental regulations direct the textile dyers to build environmental friendly alternative dyeing processes. Growing demand of natural dyed textile materials has also caused increases on the number of academic works about natural dyeing materials and dyeing processes. [1-9] Natural dyeing processes require heavy metal containing salt, mordant, as additive for the dyeing process. Eight different types

of mordant that are used as binding agent, built bridge between dye molecules and fiber surfaces.

In his study wool fiber has been dyed using vegetable-based natural dyestuff of dried walnut leaves, mint and sage using nine different mordants. Wool that is used during the experimental dyeing process is gathered from the cloned sheep Oyalı and Zarife. Cloned sheep are born in Istanbul University, Veterinary Faculty in November 2007¹. Figure 1 shows the cloned lambs.



Figure 1 Cloned sheep Oyalı and Zarife

2. EXPERIMENTAL PART

Three different groups of hand spun wool yarn samples are used in the experimental work. Two of the yarn samples are spun using greasy wool of cloned sheep of Oyalı and Zarife. (Figure 1) The other yarn sample is used as control specimen that is supplied by a local carpet yarn manufacturer.

Extract preparation

Dye extraction is prepared using boiling process at 100°C, for 60 minutes. Dried dye materials are weighed as the same weights of fiber weights. Appropriate amount of each material (walnut leaves, sage leaves and mint leaves) are boiled in the 25:1 liquid ratio of distilled water. Processed water-dye material extracts are then filtrated to remove residuals and other contaminations. Infiltrated extracts are then used during all dye processes.

Mordanting

In the experimental work plan eight different mordants were chosen: ferrous sulphate, calcium nitrate, copper sulphate, potash alum, potassiumbitartarate, caustic, soda, potassiumdichromate. The amount of mordant material is calculated based on the weight of the specimen yarn. Mordant was taken as 3% of specimen yarn to be dyed in weight. The methods of dyeing employed were premordanting. In the premordanting method, the yarns were first immersed in an aqueous solution of each eight mordant of ferrous sulphate, calcium nitrate, copper sulphate, potash alum, potassiumbitartarate, caustic, soda, potassiumdichromate.

Dyeing

After the premordanting processes, all of mordanted and non-mordanted specimens are then dyed for 60 min. at 100°C in the aqueous medium of liquor ratio of 25:1.

Colour measurement :

¹ http://www.istanbul.edu.tr/iuha/?page=print/news&int_Id=4152

Colour values were evaluated by means of K/S and CIELAB colour difference values (illuminant D65/10 0 observer) on Datacolor spectrophotometer.

Fastness determination

Wash fastness test were carried out according to the A2S method. Wet and dry rub fastness measurements are carried out using manual crock meter, with 10 cycles.

3. RESULTS AND DISCUSSION

In Figure 2, colours of dyed wool specimen that belongs to Oyalı, are shown. Colours of sage and mint dyed specimens are found similar to each other where colours of walnut dyed specimens are found different. Walnut dyed specimens are found darker than the other specimens dyed with sage and mint. Influence of mordants is also shown in the Figure 2.

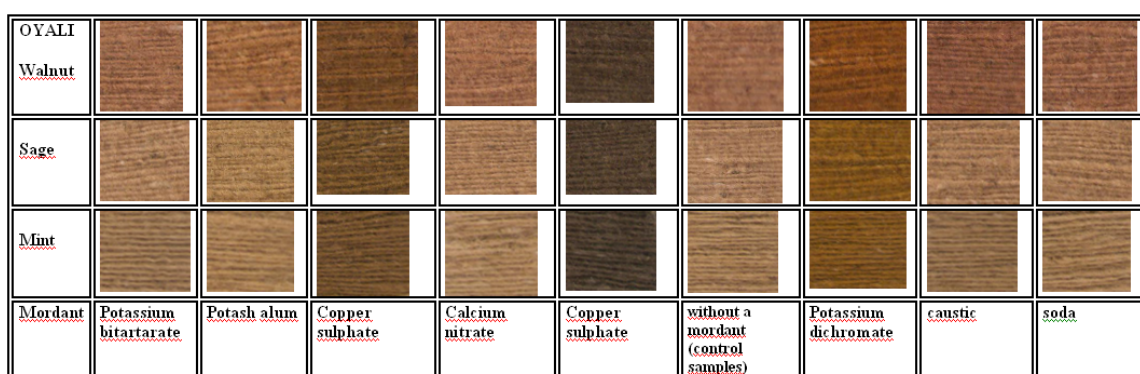


Figure 2 Colours of walnut, sage and mint leaves on the wool samples of Oyalı

K/S colour values of walnut dyed wool specimens are shown in Figure 3. Use of different mordants has similar influences on each three wool types.

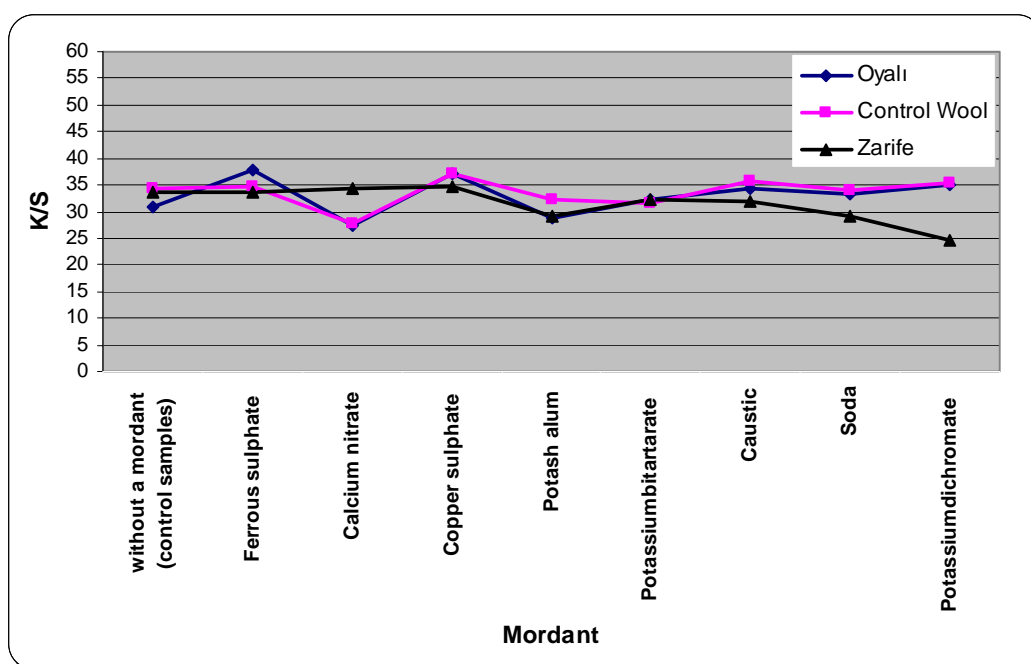


Figure 3 K/S colour values for the specimens of Zarife's wool, Oyalı's wool and control wool

	Oyali-Zarife	Oyali-control	Zarife-control
	dE	dE	dE
without a mordant (control samples)	2,53	3,66	4,19
Ferrous sulphate	1,80	2,05	0,38
Calcium nitrate	3,87	2,33	5,23
Copper sulphate	1,54	0,64	1,97
Potash alum	1,32	6,20	5,14
Potassiumbitartrate	1,63	3,24	4,64
Caustic	1,85	1,89	2,55
Soda	2,97	4,10	6,91
Potassiumdichromate	4,42	3,74	6,84

Table 1 dE colour comparisons for the specimens of Zarife’s wool, Oyali’s wool and control wool

In the Table 1 dE colour differences values of each wool group are compared with each other. The highest dE difference is found between specimens dyed with mordants of Calcium nitrate and Potassiumdichromate for the comparison of wool types Oyali and Zarife.

dE values of specimens are shown in the graphs of L, a, b in Figure4. Colour differences of each three types of wool are found parallel to each other when comparing the influences of different eight.

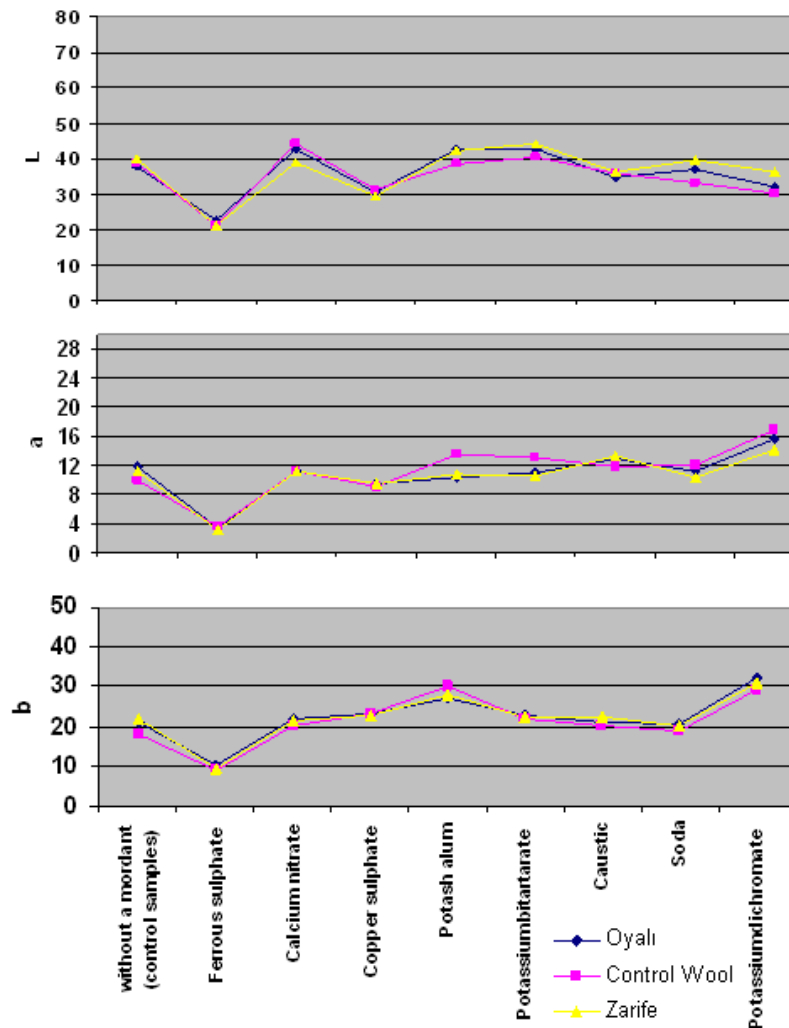


Figure 4 L, a, b values of walnut dyed wool specimens

	Oyali		Zarife		Control Wool	
	Dry	wet	Dry	Wet	Dry	Wet
<u>without a mordant (control samples)</u>	4	3	4-5	3	4	3
<u>Ferrous sulphate</u>	4	3-4	3-4	3-4	4	3
<u>Calcium nitrate</u>	4	3	4	2-3	4	4
<u>Copper sulphate</u>	3-4	3	3-4	2-3	4	4
<u>Potash alum</u>	3-4	2-3	4	2-3	4	4-5
<u>Potassiumbitartarate</u>	4	2-3	4-5	2-3	3-4	3
<u>Caustic</u>	4	3-4	5	3-4	4-5	4
<u>Soda</u>	4	3	4-5	4	4-5	3-4
<u>Potassiumdichromate</u>	3-4	3	4	3	3-4	4

Table 2 Rubbing Fastness values of walnut dyed wool specimens

	Oyali		Zarife		Control Wool	
	Staining on Wool	Staining on Cotton	Staining on Wool	Staining on Cotton	Staining on Wool	Staining on Cotton
<u>without a mordant (control samples)</u>	5	4-5	5	3-4	4-5	4-5
<u>Ferrous sulphate</u>	4-5	4-5	4-5	4	4	4-5
<u>Calcium nitrate</u>	4-5	3-4	4-5	3-4	4	4
<u>Copper sulphate</u>	4-5	4	5	4-5	4-5	4
<u>Potash alum</u>	3-4	4	3-4	3-4	5	3-4
<u>Potassiumbitartarate</u>	4-5	4-5	4-5	4	4-5	4-5
<u>Caustic</u>	4-5	4	4-5	4	4-5	4-5
<u>Soda</u>	5	4-5	5	4-5	4-5	4
<u>Potassiumdichromate</u>	4-5	4	4-5	4	4-5	4-5

Table 3 Washing Fastness values of walnut dyed wool specimens

Results of rubbing fastness and washing fastness values of walnut dyed specimens are shown in Table 2 and Table 3 respectively. Mordant types of ferrous sulphate, caustic and soda are found giving highest level of washing and rubbing fastness values considering both wet and dry rubbing conditions.

4. CONCLUSIONS

Wool samples that are coming from cloned sheep of Oyali and Zarife are found giving similar results considering influence of different dye materials - walnut, sage and mint leaves; different types of mordant, and their fastness properties.

Colours of walnut leave dyed specimens are dyed mostly in the range of brown, where sage and mint leaves dyed specimens are found in mostly khaki colours.

ACKNOWLEDGEMENT

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A STUDY ON THE NEEDLE HEATING FOR SEWING DENIM FABRICS

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Keywords: Needle heating, denim fabric, spun polyester, polyester-cotton corespun, thermal camera, thread damage

Abstract: *Needle heating is a serious problem that limits the further increase of the sewing speed, and hence the productivity. During the process, the needle temperature varies in every stitch as the needle punches through and withdraws from the fabric. The high temperature in the needle can degrade the strength of the thread. It may cause the wear of the needle eye, which may damage the thread. It can also scorch the fabric, and weaken the needle. According to the literature, needle heating is affected by fabric thickness, fabric finish or density, sewing machine speed and needle contact surface. In this study, three denim fabrics which have two plies have been sewn with spun polyester and polyester-cotton corespun thread at 2000 rpm. Several physical tests were carried out in both threads and fabrics. Also, thermal camera has been used to identify the temperatures of the needles during the sewing process. The images of a sewing process and the temperatures are obtained from the thermal camera. The observations have shown that the needle temperatures were ranging within 32 °C - 60 °C on the thermal camera. Additionally, the thread structures were observed under the light microscope and the overall results were discussed.*

1. INTRODUCTION

Industrial sewing is one of the most commonly used manufacturing operations. Every day, millions of products ranging from shirts to automotive airbags, are sewn. Hence, even a small improvement may result in significant corporate benefits.

In recent years, high speed sewing has been used extensively to increase the sewing productivity. In industrial sewing, typical sewing speeds range from 1000-3000 rpm. However, when working with high speeds of sewing, thread may break easily. Broken thread may be caused by various reasons, especially excessive needle heating being a serious problem. When the needle penetrates the fabric at thousands of times per minute, needle heating is generated to a friction between the needle and the fabric. The friction generates heat, part of which is absorbed by the fabric and needle. Depending on sewing conditions the

maximum needle temperatures range from 100-300 °C¹. This high temperature can cause the wear of the needle eye and damage in the thread. Figure 1 gives an image of thread breakage and needle holes caused by needle heating. It has been observed that the high needle temperature is caused the melting point of the synthetic sewing thread, resulting in broken threads. Also, the hot needle may initiate damage in the fabric, such as leaving burn marks on natural fibres, leaving a weakened seam or melted residue on the fabric surface. Decreasing the sewing speed can reduce the needle heating; it will also decrease the productivity¹.

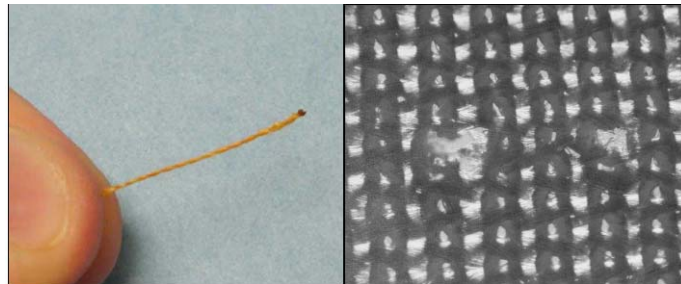


Figure 1: a) Thread breakage due to needle heat b) Needle holes caused by needle heat²

1.1. The Basic Thermal Mechanics of Needle Heating

The needle heating process is a complicated process. Figure 1 illustrates the thermal dynamic system of the needle heating. The heat sources include the following³:

- The heat flow generated from the friction between the fabrics and the needle. Note that with the motion of the needle, the fabric position relative to the needle is changing during a stitch.
- The heat flow generated from the friction between the thread and the needle-eye when the thread is in tension. Since, the thread tension is varying within a stitch.

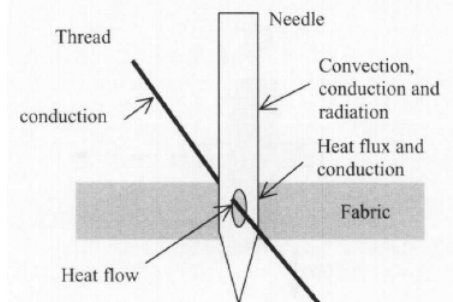


Figure 2: Illustration of needle heating³

The heat sinks include³;

- The convection of the portion of the surface of the needle that is not in contact with the fabrics
- The heat conduction in the needle from the higher temperature points to the lower temperature points
- The heat conduction to the fabric, as the needle temperature is higher than the fabric
- The heat conduction to the thread, which happens when the thread loosely passes through the needle eye
- The radiation from the needle surface to the environment.

1.2. What Causes Needle Heating?

The friction between the needle and the fabric creates a heating in the needle and it is known that the following factors can have an impact on the amount of heat that is generated²:

- Fabric thickness,
- Sewing machine speed and
- Needle contact surface.

For this in mind, we have set the sewing machine speed constant for this study to observe the effect of the fabric thickness and thread type to see if any heating is going to occur during the sewing process of denim fabrics.

2. EXPERIMENTS

In this study three denim fabrics which have two plies have been sewn with spun polyester and polyester-cotton corespun thread at 2000 rpm. Several physical tests were carried out in both threads and in fabrics under the standard atmosphere conditions regarding to the TS 240 EN 20139⁸. Also a thermal camera (IRISYS 4040) has been used to identify the temperatures of the needles during the sewing process.

2.1. Fabrics

Table 1 shows the fabric properties and their tenacity results. Tensile strength of these fabrics were determined according to ASTM 5034⁴ by using Goodbrand, stiffness according to ASTM 4032⁵ by using J.A.King, elongation according to ASTM 3107⁶ Dupond and tear strength according to the ASTM 1424⁷ by using Textest.

Fabric Code	Thread Components	Weight of fabric g/cm ²	Fabric Components	Weave type	Tensile Strength (kg)	Tear strength (g)	Stiffness (kg)	Elongation (%)
A	warp:100%CO weft:100%CO	0.03	100% CO	3/1 Twill Right	warp: 72.2 weft: 41.2	warp: 4600 weft: 2766	0.5	warp:4.8
B	warp:100%CO weft:97/3% PES/ Lycra	0.04	64.5/34/1.5 % CO/PES/Ly cra	3/1 Twill Right	warp: 90.4 weft: 132.6	warp: 7296 weft: 9565	2	warp:4.8
C	warp:100%CO weft:100% CO	0.05	100% CO	3/1 Twill Right	warp: 122 weft: 74	warp: 6024 weft: 3852	2	warp:8

Table 1: Denim fabric properties and tenacity results

2.2. Sewing Threads

It was recommended in a previous work⁹ that lightweight denim fabrics can be sewn with either finer polyester threads or coarser cotton threads and heavyweight denim fabrics can be

sewn with either coarse corespun threads or coarse polyester threads. Therefore, in this current study, we have chosen the threads (spun polyester abbreviated 1 and cotton/polyester abbreviated 2) as can be seen in Table 2 and it shows their test results. Tensile strength and elongation of threads were determined according to TS 245¹⁰ by using Statimat and Testometric M 250, twist according to TS 247¹¹ by using Zweigle D 312, hairiness by using Zweigle Hairiness Tester G566, thread count according to TS 244¹² by using Mettler and shrinkage according to TS 392¹³ standards.

Thread Code	Thread count (dtex)	Strength (cN/Tex)	CV%	Elongation (%)	Twist (tpm)	Shrinkage (%)	Friction	Hairiness N3 (<3mm)
1	290x2	2368	5.91	16.5	592	0.2	16	952
2	200x3	2812	2.27	22.2	671	0.2	18	472

Table 2: Test results of sewing threads

2.3. Needle Size

Needle size was chosen according to the fabric thickness and weight. Needle no. 18 was used for all three denim fabrics.

2.4. Sewing Parameters

Sewing process was carried out on Juki DDL-9A-SS sewing machine and sewing parameters can be seen below:

- Machine speed: 2000 stitches/min
- Seam geometry: plain lock stitch seam
- Linear stitch density: 5 stitches/cm

3. RESULTS

In this study, three type of denim fabrics which have made two plies during the sewing process were sewn with spun polyester (thread code 1) and polyester/cotton corespun thread (thread code 2) at 2000 rpm. During the sewing process, thermal camera has been used to identify the temperatures of the needles. Figures 3-8 show the thermal images of needle heating at 60 s.

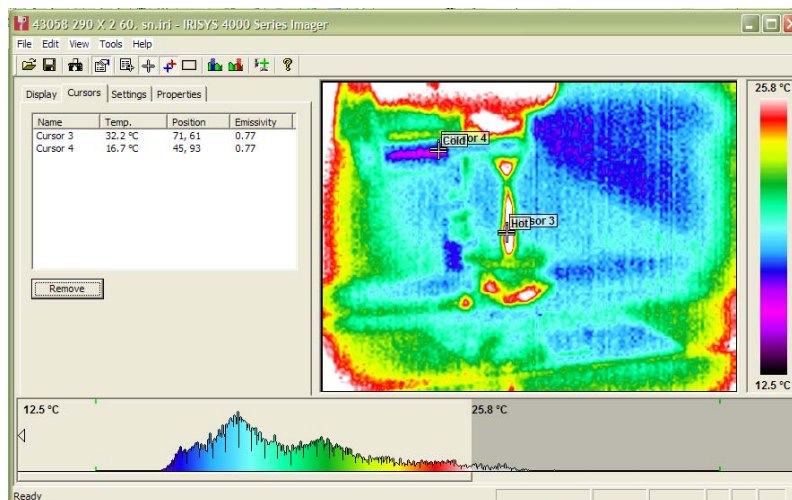


Figure 3: Thermal image at 60 s of the fabric A sewn with 290x2 dtex spun polyester

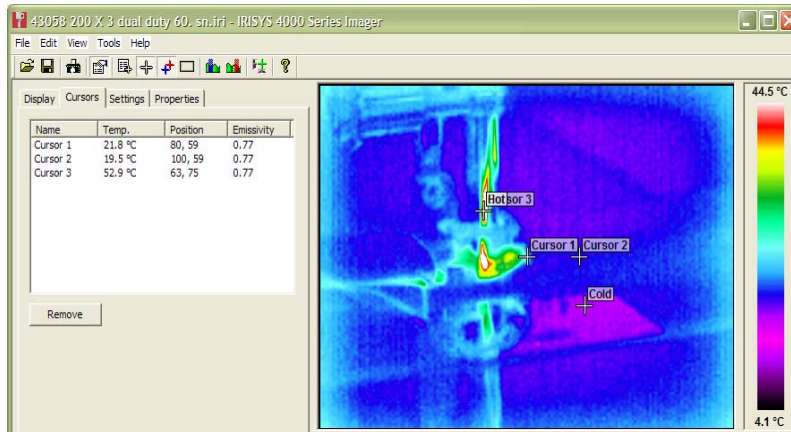


Figure 4: Thermal image at 60 s of the fabric A sewn with 200x3 dtex corespun cotton/polyester

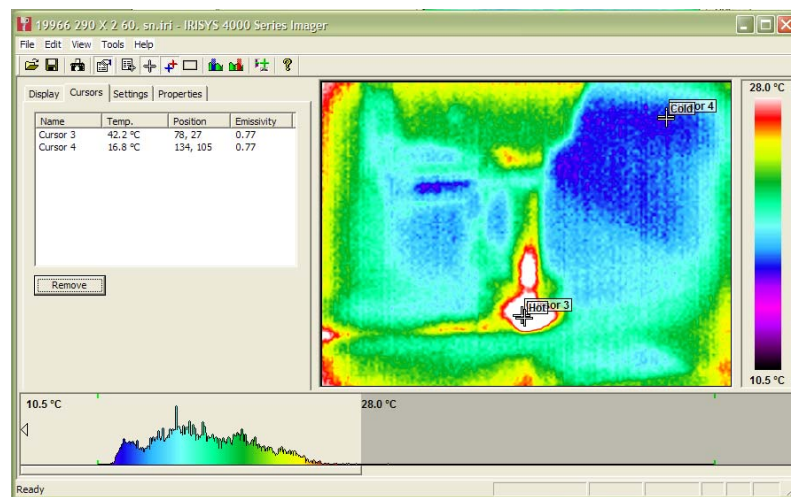


Figure 5: Thermal image at 60 s of the fabric B sewn with 290x2 dtex spun polyester

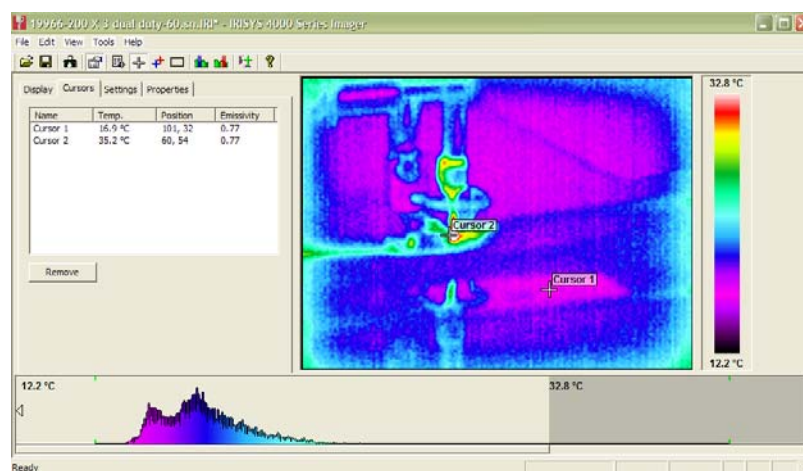


Figure 6: Thermal image at 60 s of the fabric B sewn with 200x3 dtex corespun cotton/polyester

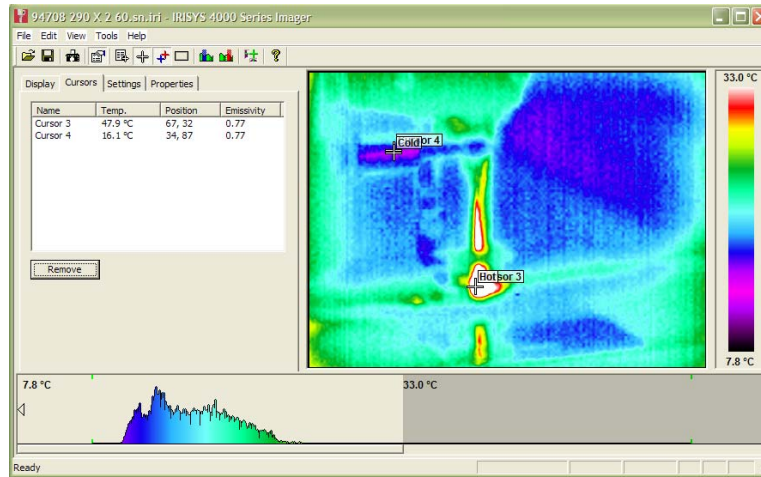


Figure 7: Thermal image at 60 s of the fabric C sewn with 290x2 dtex spun polyester

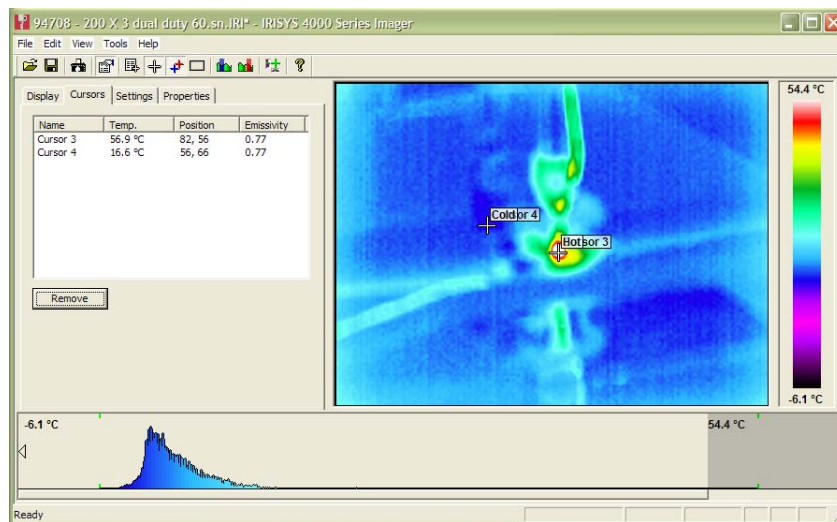


Figure 8: Thermal image at 60 s of the fabric C which sewn with 200x3 dtex cotton/polyester corespun

The needle temperatures are given in Table 3 which was sewn with 200x3 dtex cotton/polyester corespun thread.

Fabric code	Needle temperature at 15.seconds (°C)	Needle temperature at 30.seconds (°C)	Needle temperature at 45.seconds (°C)	Needle temperature at 60.seconds (°C)
A	47.6	48.7	50.0	52.9
B	49.4	59.7	40.9	39.0
C	43.8	44.5	51.1	56.9

Table 3. The temperatures of needle

The needle temperatures are seen in Table 4 which was sewn with 290x2 dtex spun polyester thread.

Fabric code	Needle temperature at 15.seconds (°C)	Needle temperature at 30.seconds (°C)	Needle temperature at 45.seconds (°C)	Needle temperature at 60.seconds (°C)
A	39.7	40.0	36.5	32.2
B	36.1	38.3	38.5	42.2
C	34.9	45.7	37.9	47.9

Table 4. The temperatures of needle

The needle temperature (°C) versus sewing time (s) can be seen in Figure 9; from this graphic it can be observed that the maximum needle temperature (around 60°C) obtained on the B fabric at 30 s with the coded thread 2 which is made of corespun cotton/polyester. On the other hand, the minimum needle temperature (around 32 °C) was obtained on the A fabric at 60 s with the coded thread 1 which is spun polyester. Both A and C fabrics have shown an increase in the needle temperature after the 30 s of sewing time with using the cotton/polyester corespun threads. The needle temperature shows decrease in sewing the fabric A with the spun polyester thread after the 30 s. The fabric B has shown a great decrease in needle temperature after 30 s on the cotton/polyester corespun thread (see Figure 9 fabric B with thread 2).

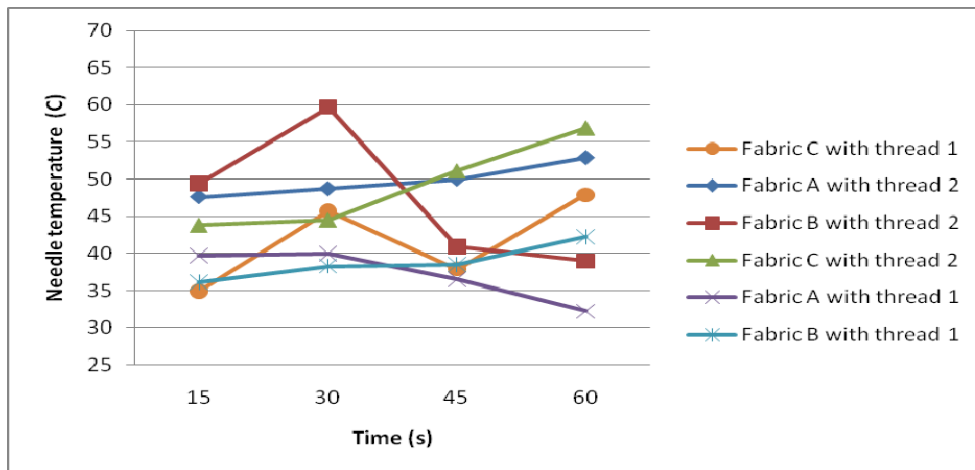


Figure 9: The needle temperatures during the sewing of denim fabrics

The threads (upper and lower parts of the bobbin case) were also observed under a light microscope to see if there are any damages within the yarn due to sewing process; some of these related samples were presented in Figures 10-13.



Figure 10: Upper thread (290x2dtex spun polyester: coded as thread 1) used in fabric A



Figure 11: Lower thread (290x2dtex spun polyester: coded as thread 1) used in fabric A



Figure 12: Upper thread (200x3dtex corespun cotton/polyester: coded as thread 2) used in fabric C



Figure 13: Lower thread (200x3dtex corespun cotton/polyester: coded as thread 2) used in fabric C

4. CONCLUSION

In this paper, needle heating was studied on the sewing of denim fabrics. For this, slightly different in weight of three denim fabrics were sewn in two plies with spun polyester and polyester/cotton corespun threads at 2000 rpm. The thermal camera has been used to identify the temperature of the needles during the sewing process and the sewn threads were also observed on the Olympus SZ60 light microscope under 6.3x magnification (see Figures 10-13) to see if any damage can be occurred in the sewing threads due to the heating of the needle. The following conclusion can be made:

- The 100% cotton denim fabrics which are sewn with cotton/polyester corespun thread gives higher needle temperature than the cotton/polyester/lycra denim fabric.
- Generally, the less strength and the very slightly lower in weight of 100 % cotton denim fabric has given the lowest needle temperature during the sewing with spun

polyester thread; this may be due to the structure of the yarn and its more hairiness and less twist within the yarn. It is thought that the more fibres protruding the yarn body may absorb the more heat of the needle that may occur during the sewing and also as the twist is less within the unit of the thread may help to act as an aerodynamic property for the thread during the sewing and hence the friction between the components of needle/thread and fabric.

- From the micrographs it can be interestingly concluded that lower threads in the bobbin case are seen to have slightly more impaired than the upper threads. This needs further study.
- Needle heating has more effect on the corespun cotton/polyester rather than the spun polyester threads; this might be either from the friction between 100% cotton denim fabric and corespun thread which is made of cotton, too on the outer section of the yarn itself that may cause fibre-fibre friction between the two cotton surfaces (fabric and thread) or might also be from the brightening of the spun polyester thread that has in its surface structure.
- From the thermal images, it can be concluded that the higher temperatures were obtained at the needle eye of the sewing machine which was expected. This may then cause a slight damage to the sewing threads which are made of synthetic fibres; this has also been noticed on the micrographs where the stitched and unstitched thread samples presented de-fibrillation (more hairy surface on the surface of the thread) within the yarn body that can be detected.
- Although this study only was carried out for a very short time of period (1 minute and fewer times due to the thread run out at the bobbin case) it would be better to extend the observation time to see how the needle temperatures changes during sewing process for further studies.

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INTERNATIONAL COOPERATION AND PROJECT-BASED MANAGEMENT IN TEXTILE RESEARCH AND DEVELOPMENT

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Keywords: management, project-based management, R&D project management, international cooperation

ABSTRACT: *International economic cooperation is the most modern and equitable form of exchange between the states and the many-sidedness of the international economic relations is a consequence of the necessity to solve the global problems.*

On the other hand, research, development and innovation are vital, as they allow for better meeting the needs of the citizens as individuals and of their communities.

Currently there is a trend toward elaborating and implementing coherent development strategies, planning and organizing from a project perspective. Well defined projects are the basis for development by creating international consortia in which project management is transformed in project – based management.

Determining and meeting the conditions for successful research and development projects in the textile field are necessary in the actual economic crisis when human, energy and material resources are limited, especially when there is tough competition specific to globalization. Therefore, detailed knowledge of the management process specific to research – development projects is needed.

1. INTRODUCTION

The essential elements that support and promote innovation are research and development, as well as advanced technologies.

Despite its very long chain of production that consists in at least 26 different actions, *the field of textile and clothing in the European Union* has a long management tradition in innovation and creativity. The EU textile industry is also well known for the pioneering role it plays internationally due to a high degree of competitiveness and innovation.

The textile industry is a component of Romanian economy that generates foreign currency, contributes to a balanced regional development, social stability and an environment that fosters private initiative. The textile industry has a clearly defined essential role in the national industry policies mainly because of its contribution to creating jobs. Therefore, it is important that it is supported and strengthened as a key employer field.

Presently the economic and social development of the society is based on the project concept in all the activity fields.

Project – based management is a new management element, a specific way to adapt management to the actual scope and rhythm of the technical – scientific progress and global

competition. Due to its complexity, *a modern project* requires a new vision in its implementation – it starts with an analysis of the needs and ends with an efficient application of the results obtained.

2. STRATEGIC ENVIRONMENT OF NATIONAL AND INTERNATIONAL PROJECTS

The main *aim* of the cooperation activities and international partnership as well as that of the support measures is to integrate Romanian community in the international community, especially in the European community by means of:

- Increase of the efficiency and effectiveness of research – development – innovation of production and services by the acquisition of modern techniques in international projects management;
- Increase of the excellence level, harmonizing the national development tendencies of science, technology, production and services with international registered tendencies.

International Cooperation and partnership are based on the following *principles*:

- The existence of a mutual and measurable scientific, technological, economic or commercial advantage;
- The approach of international collaboration within a cooperation framework that has the highest impact over the national economy;
- Complementarity of international collaborations with national programmes;
- Attracting external research – development sources and capitalization of the national results on the external markets, including the developing countries;
- Integration in the high performance national, European and international networks.

The main *objectives* of international cooperation and partnership are:

- To obtain scientific and technological excellence on a national level in a globalization context;
- To strengthen the national capacity to research and develop, to produce and to provide services; to increase the efficiency of the use of the scientific and technological potential and of the results' applicability;
- Achievement of significant contributions in meeting specific policy objectives in the national economy, in accordance with the foreign policy;
- To stimulate the participation of the Romanian specialists in international programmes;
- To stimulate the participation of foreign specialists in national programmes of research and development, production and services;
- To increase the national education level and living standards.

The main strategic objectives of international cooperation and partnership are:

- To form and develop practices in accordance with the enforced regulations in the field of intellectual and industrial property;
- To promote the cooperation of enterprises and organizations within European and Euro – Atlantic cooperations aimed to obtain significant benefits for the participants;

- To facilitate the access to reputable research centres and to research centres within enterprises that have prestigious scientific and technological results with the aim to obtain scientific and technological knowledge comparable to that of global level and to use it in national interest projects;
- To establish modern concepts in the organization and management of production, services, research – development – innovation and their integration in the market economy;
- To stabilize and strengthen the national capacity at an international level.

3. NATIONAL AND INTERNATIONAL PROJECTS IN A GLOBAL COMPETITIVE ECONOMIC SYSTEM

Economic globalization is a result of two different still complementary factors: decrease of transportation and communication costs and on the other hand the liberalization of the flows of capital, goods, services and labour force.

At one extreme, the global economy cancels distances while at the other extreme the economic globalization implies the elimination of all customs taxes. These characteristics prove that the present stage of the world economy is still far enough from reaching a sufficient level of globalization.

The economic globalization is considered by some a threat, while others view it as an opportunity for economic growth and development. Nevertheless, the economic globalization is an unstoppable force in any economy.

The economic agents in various sectors are associated under various forms in order to reunite the capacities for scientific research and technological development, the production, delivery and services capacity with the aim of getting maximum benefits. The result is that various societies active in the same sector or in adjacent sectors reunite in research, production or service provider consortia in order to implement major projects that solve common interest problems and address at the same time local or national interests. Due to the technical and financial complexity such themes cannot be addressed by one individual company. The cooperation within such consortia is a prerequisite for successful coping with the competition in a globalized economic system.

The benefits gained contribute to the economic growth of the organizations in the consortia, of the countries that are part of the respective organizations or of the state unions corresponding to those countries. At the same time, the people who are part of these organizations have also experienced an increase in their wellbeing. Given this context, no state, no matter how strong, can cope on its own with the contemporaneous development or sustain the technological competition. This results in efforts to integrate, to set up state unions like the European Union, Asia-Pacific, NATO, Andean Community, CACM, Mercosur, NAFTA, etc.

The organization and planning of international projects needs to take into consideration the international governmental organizations, the geographical distribution of the consortium partners with their respective political and cultural – educational characteristics, as well as the structure of international companies and their respective economic and financial specifications. The objective is to achieve economic efficiency and maximum profits for the members of the consortium while complying with national and international regulations and laws. (Fig. 1)

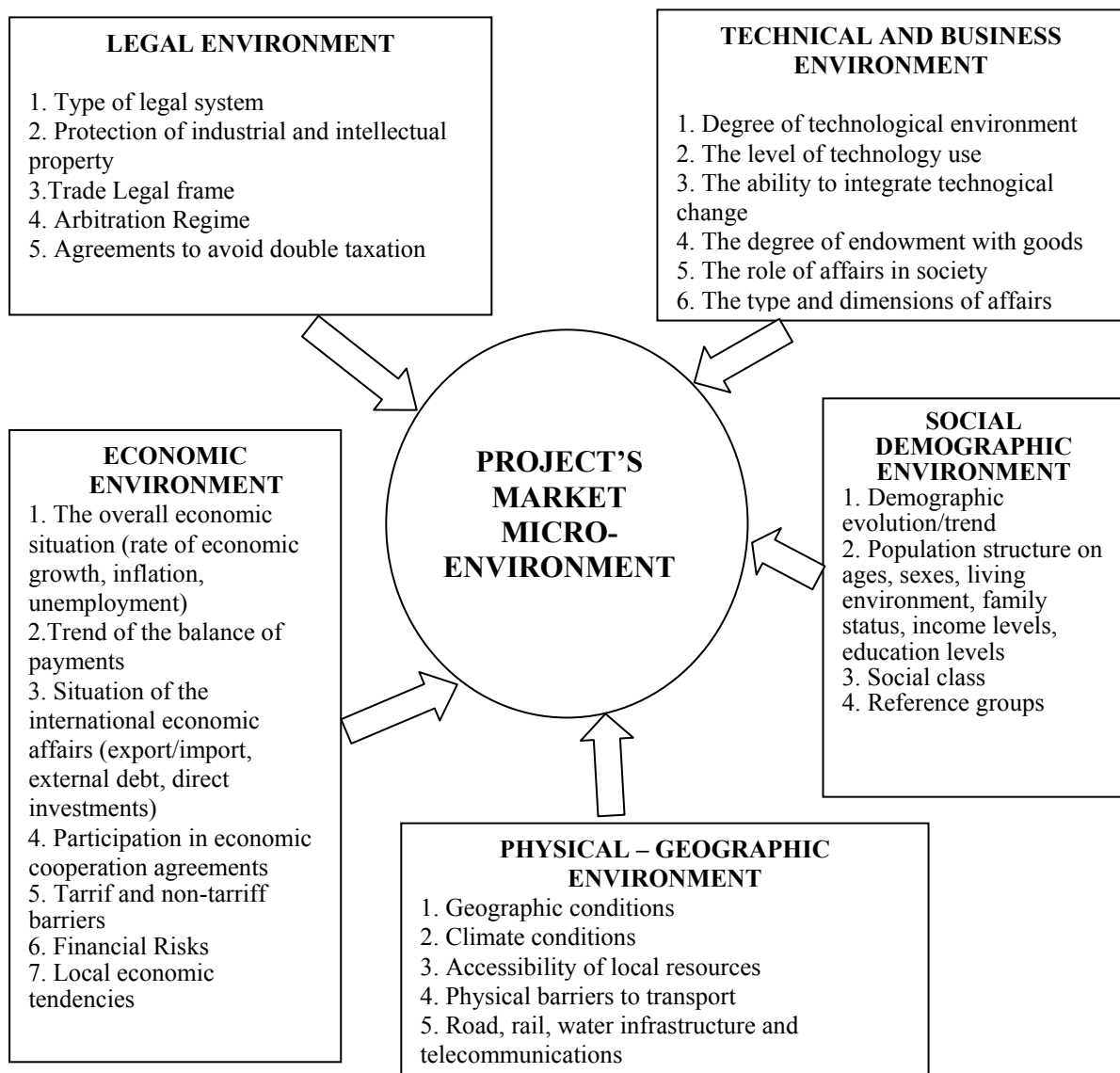


Figure 1: Components of macro environment and their interaction with the project's market microenvironment

In an economic environment the projects' success depends on establishing transnational teams that transgress time, space, cultural and language barriers. When elaborating and implementing a project one should take into account the projects' strategic environment.

4. INITIATION OF NATIONAL AND INTERNATIONAL PROJECTS

All national projects have at present a strong international character because they are highly influenced by the international strategic environment as a consequence of a globalized

competitive economic system.

An adaptable change is needed in an uncertain globalized and competitive environment. Adaptable change generates a need for projects. The companies need to adapt to the market by developing new products/services within alliances set with other companies. Each of the new elements are brought within alliances by creating new project consortia.

As a consequence, the project management abilities transcend the companies' and corporations' limits and lead to the creation of orientated careers. Professionals in all fields are attracted by change and change is translated into projects. Knowledge will be a key resource and will flow more efficiently than money. Not everybody can win, so the competition will be tough in the future. Employees who count on knowledge will stop being simple subordinates and will become specialists, professionals. They shall impact the project, the consortium and the companies because the structure productivity will rely on these specialists' knowledge. These employees will be aware in a first stage of the aims of the respective structure. In a second stage they will achieve the objectives through abilities characterized by professional and personal processes. This contrasts with the old style employees who need to be told what to do.

The key words for these specialists are *professional strategy and competence*. As long as the companies will change, people will have to adapt and those who cannot will have to leave. Those who stay will have to restructure the activity due to the need to work in a team on a project.

In order to achieve the aimed objectives, these people are permanently responsible for the acquisition of needed information, information dissemination and development of control mechanisms in the team.

5. THE IMPORTANCE OF PROJECT MANAGEMENT

Project management is the future trend. There is interest and highlight on project management as an opportunity for a management system to develop in many industrial and business sectors. Project management developed during the last 50 years due to efforts of academics and practitioners. The practitioners have worked on projects and developed the empirical basis of today practices. The academics conducted numerous studies in order to improve the project methods. Both categories contributed through a wealth of articles and books to the description of project management theory and practice.

Project management is aimed at meeting the demands of the forecasts and preventions that are inseparable in a project.

A forecast is an action that considers a future event as probable and it takes into consideration the possibilities. It organizes in advance and takes decisions that affect the future. Should we designate as favourable and possible an event that we analyze, the probable is a ratio between favourable and possible events.

When dealing with a project, forecasts are not enough, we should guess the unpredictable, the biggest cause of failures. Active prevention refers to a project in its unfolding starting with its development. It focuses on preventing deviations or dangerous variations from the objective.

Therefore, the following measures should be taken within a project:

- forecasts to identify what is possible;
- preventing catastrophes;
- inventory of the events that cannot be eliminated and elaboration of a plan to cover the already known risks.

A good project manager needs to know and to master the critical factors that can lead to a successful implementation of a project: close collaboration relations between the team members, clients and beneficiaries; a project plan that draws the direction, clear responsibilities and specific indicators to measure the progress in the project execution; continuous and efficient communication of all the participants in the project; competences control; management support.

Project Managers as well as other professionals should fulfil *four requirements*:

- *Knowledge* – understanding of the project management theory, of the concepts and practices;
- *Skill* – capacity to use the techniques and methods of the profession to obtain the expected results;
- *Ability* – capacity to integrate and use the knowledge and the skills in various ways;
- *Motivation* – an ability to maintain a desired level of values, attitudes and aspirations that help all the participants in the project to work together to finalize the project.

A national or international project materializes the willingness of all partners to work together – organization, client, beneficiary, colectivity – and it translates necessity into quantified terms:

- a. Objectives;
- b. Possibilities to achieve: human, technical, financial;
- c. Organization's competency;
- d. Leadership methods;
- e. Precise and coordinated actions;
- f. Evaluation of the results.

Project management allows fulfilling the following optimum conditions for projects' finalization:

- Increase of the overall efficiency of the activity through an orientation on results, improvement of the interdepartmental coordination and of the personnel morale;
- Reduced time to develop an organization, lower costs, and higher quality and higher profit margins;
- Very good control of the resources;
- Better relations with clients.

On the other hand, project management can lead to:

- Increase of the organization complexity;
- The tendency to trespass the organization's internal policy, due to a high degree of autonomy of the personnel involved in the project based actions;
- Increase of the costs of certain activities, difficulties in the organization, incomplete use of the personnel in the framework between two projects¹

¹ Lidia Niculita, research projects management, Editura Conspress, Bucharest, 2009

6. RESEARCH AND DEVELOPMENT PROJECTS MANAGEMENT

Research and development project management is based on the following fundamental elements that can be considered *principles* of this specific management:

- The necessity to apply three stages for a project: planning, control and improvement of the quality of activities;
- Analysis of the research processes by component elements;
- There is no management without manager and the project's management quality reflects the manager's quality;
- The project director as a manager must establish clear and firm rules and procedures for the operation of the research team and of the project partners;
- The need to improve continuously the quality of the activities and the results of researches;
- The need to foster the team spirit;
- Subordination of the individual interests to the project interests;
- Cultivate the intrinsic link between the research processes and the personnel training processes;
- The need of unique leadership for the project objectives;
- Rational and economic use of all the resources;
- Systematic evidence of all the resources;
- Material and moral stimulation of personnel for the increase of efficiency and effectiveness of the research;
- Correct and equitable compensation.

The main aim of a research and development project is to elaborate a project proposal, to win and to secure project financing and co-financing, to execute the plan in accordance with the project, within the terms and volumes of financial resources, to get the results and the planned indicators and to reach the planned objectives through transfer in the economy of the results obtained in the research – development project.

The work towards the main objective is led by the project director who is the project general manager as well as by the other managers together with the research teams belonging to all the partners in the research –development consortium.

The research – development management has the following functions:

- To establish and to formulate in a clear and precise manner the project objectives and to communicate them to the project team
- To provide the needed resources, the logistic and the infrastructure needed for the project
- To organize the research and research - related activities
- To motivate, train and lead all the research and auxiliary personnel so that they get involved in the execution of the project
- To control and to monitor the objectives of the projects' stages, including economic indicators
- To ensure quality during the project implementation
- To capitalize on the results through technology transfer or through wide dissemination of the knowledge gathered as a result of the project implementation.

7. CONCLUSIONS

The economic success is influenced by the increase of added value through scientific research by means of project management technology in a globalized competition.

The future belongs to a project centred organization, unlike the organization on departments working on different segments of a project. *In this case, the project dictates the departmental structure.* The performance of an organization is not measured by the organization's strength but also by its adaptability to projects.

Consequently, the participation in projects in international programmes is a prerequisite for existence in the globalized competitive economic system. The participation relies on the development, adaptation and implementation of national projects in the international programmes in accordance with corresponding international themes and solutions to national problems.

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LATENT PIGMENTS- PREPARATION, CHARACTERIZATION AND USE IN HIGH-REMANENCE DYEING OF KERATIN FIBERS

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This paper presents research undertaken in order to achieve a new absolute global process for dyeing keratin fibres (wool) using non-specific colouring material, organic pigments respectively *latent pigments*.

Unlike traditionally used dyes, organic pigments are substances totally insoluble in water and organic solvents so they cannot be used as such in the dyeing of the wool in aqueous medium.

The purpose of this research is the synthesis and conditioning to obtain a minimal assortment of latent soluble pigment that can be used for wool dyeing in aqueous medium, then by post-dyeing treatment (chemical reaction, thermal or photochemical treatments) to be converted directly in fiber, to form the initial structure of organic pigments (post-dyeing treatments cause breaking the links between the radical chromophore of the pigment and the water-solubilizing groups.)

Materials and methods: In our study we focused on the synthesis and processing by conditioning of organic pigments, because the exceptional physical-chemical and colour characteristics of the pigments are well known. Research taken pigments were: *PR122, PBI 15:4 and PO34*.

Methods of preparation of latent pigments:

- ▶ Nano-dispersing and functionalization of organic pigments to obtain the “latent pigments” and their physical-chemical characterization;
- ▶ Composition of aqueous formulations for dyeing of the wool

The process for dyeing keratin fibres (wool):

- ▶ Dyeing, similar to the classic wool dyeing
- ▶ Post-dyeing treatment of the latent pigments directly in fiber by selecting the following options: chemical, thermal or photochemical treatment, respectively the reconversion of the latent pigments into initial water-insoluble pigments.

Results:

- Obtaining a minimal assortment of latent pigments in the basic colours: Blue (PLBI 15:4), Red (PLR 122) and Yellow-Red (PLO 34);
- Establish procedures for dyeing and post-treatment of the wool fabric in aqueous media.

Design, Fabrication and Characterization of Flexible Dye-Sensitized Photovoltaic Fibers

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Abstract: *Dye-sensitized solar cells (DSSCs) that were first introduced by Gratzel's group in 1991 are regarded as a promising third-generation photovoltaic cell to replace conventional Si-based solar cells thanks to their outstanding cost-effectiveness, high energy conversion efficiency and simple fabrication process. However, due to the high rigidity of the transparent conducting oxide (TCO) coated glass substrates used in DSSCs, they have faced limitations in transformation, installation and application. To overcome these problems, DSSCs have been fabricated in various forms and further studies on fibrous flexible DSSCs are required.*

Dye-sensitized photovoltaic fibers were fabricated using porous films prepared by the phase inversion process and their photocurrent-voltage (I-V) characteristics were estimated. A TiO₂ layer coated titanium (Ti) wire and a platinum (Pt) wire were used as the working electrode and the counter electrode, respectively. The Pt wire was coated with a porous film to prevent contact between the two electrodes. As the immersion time in water was lengthened, the pore size distribution in the porous film gradually broadened and the photovoltaic performance of the fibrous DSSCs enhanced due to the facilitated electrolyte penetration.

The photovoltaic characteristics of fiber-shaped DSSCs fabricated with metal wire electrodes were also studied.

PROJECTING BREAKING FORCES OF SEWED SEAMS

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Keywords: breaking force, sewed seam, projecting, stitch density, thread

Abstract: *During wearing, clothes are exposed to different stresses depending on body movement, cut, material, etc. Large stresses can damage the clothes and lead to seam deformation. Therefore, the seams have to fulfil the criteria established by the sewing process and clothes exploitation. Projecting breaking forces of sewed seams has always been a very important issue in the apparel industry. Having applied theoretical assumptions and experimental results, the method for projecting breaking forces of sewed seams (stitch type 301 and 401, stitch mark 1.01.01, according to ISO) with cotton fabric for shirts has been developed. Furthermore, some equations that can be used for predicting breaking forces of sewed seams depending on stitch density and characteristics of applied threads have been developed.*

1. INTRODUCTION

During wearing, clothes are exposed to different influences and stresses. Those stresses mainly depend on body movement, clothes' cut, manufacture, material, etc. High stresses may damage the clothes or cause deformations that can usually be noticed at seam area (thread slippage), at seams (thread breakage) and sometimes on the material itself. If we compare changes of body's dimensions at different movements and stretching of different kinds of fabrics, it can be seen that very few fabrics have appropriate stretchability to sustain the body movements. The lack of stretchability is compensated by adding commodity material in order to improve wearing comfort and to reduce stresses at seams.

Projecting breaking forces has always been an actual problem in garment production. This problem requires a very complex data processing related to fabrics and joining elements i.e. sewing threads, seams and stitches.

While testing fabric samples in dynamometer, with seams in cross direction relating to the seam, the stress q (mobile clamp 2) is uniformly applied (Figure 1a). Reaction q' (N/cm) can be noticed at upper clamp 1, which is also uniformly applied stress even to q , i.e. $q = q'$.

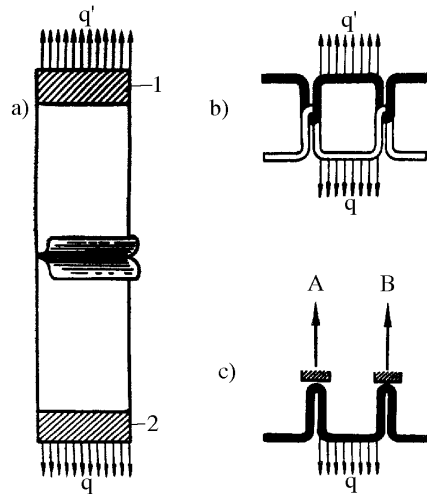


Figure 1. Tensile load of seam at the stress in cross direction:
a) clamped sample at the dynamometer, b) and c) stress application in the stitch

If we know the value of the force, added to the lower clamp 2, the tensile load q will be as follows:

$$q = q' = \frac{F}{b} \text{ (N/cm)}, \quad (1)$$

where: q - tensile load of the sample at mobile clamp 2 (N/cm),

q' - tensile load reaction q (N/cm),

F - retraction force of lower clamp (N),

b - the width of the sewed sample i.e. the sample width on the dynamometer (cm).

Ideally, if we monitor the application of force at a single stitch type 301 (Figure 1b), it is obvious that all threads in each stitch are subject to stretching.

Having in mind that $q = q'$, it can be noticed that no thread migration can be seen at the knitting points. Therefore, our task is defining reactions in side stitches (Figure 1c). According to the theory of material resistance upon the force of lower clamp movement, values of reaction forces A (N) and B (N) can be found. These forces will, in that case, characterize the strength of the thread that is used in the seam:

$$F_T = A = B = \frac{q \cdot a}{2} \text{ (N)} \quad (2)$$

or

$$F_T = \frac{F \cdot a}{2 \cdot b} \text{ (N)}, \quad (3)$$

where: a – stitch length (cm), equal to $a = b/n$,

n - number of stitches in the sample.

If we change the values for a stitch length in the last formula, we get:

$$F_T = \frac{F \cdot a}{2 \cdot b} = \frac{F}{2 \cdot n} \quad (\text{N}). \quad (4)$$

The breaking force of the seam F , joined by stitch type 301, can be expressed as follows:

$$F = 2 \cdot F_T \cdot n = 2 \cdot \frac{F_T \cdot b}{a} \quad (\text{N}). \quad (5)$$

If we know the values of initial breaking force and weakening coefficient of a thread in the process of stretch formation η , the previous formula can be written as follows:

$$F = 2 \cdot F_{T1} \cdot \eta \cdot n \quad (\text{N}), \quad (6)$$

where: F_{T1} - initial –breaking force of a thread (N),
 η -weakening coefficient

In order to use the given formula, it is necessary to experimentally determine the value of weakening coefficient in different conditions of stitch formation. The deviation is in the range of 3 % to 8 %.

Having examined the forming and shaping stitches, it can be noticed that, due to the presence of stretching and abrasion forces in knitting upper and lower thread, condensation of warp and weft threads occurs. The level of seam deformation is the highest at that point and it is gradually smaller while we move towards the middle point. Because of that, the geometrical shape of the stitch is changing. Figure 2 shows graphics of seam with stitch type 301. If that seam is subjected to stress, the loading will be carried through thread system to the thread and it will cause even higher level of fabric condensation (Figure 2b).

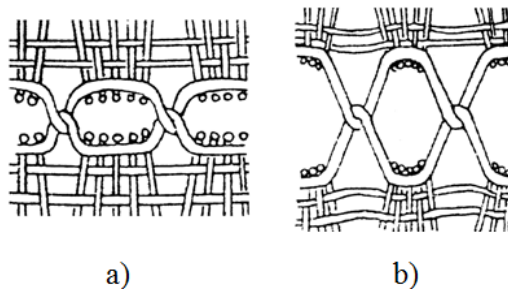


Figure 2. The seam with stitch type 301:
a) prior loading, b) during loading

On the basis of seam breaking forces analysis and the instability of fabric wires and seam threads caused by the loading, it is necessary to introduce during projecting breaking forces of sewed seams appropriate correction coefficients that will take into account this fact.

2. Experimental part

As the sewing process is very complex and the demands for seams made in garment production are numerous, this research should improve the development of projecting breaking forces of sewed seams. Therefore, overall measurements of breaking forces were

carried out.

Research methods

One of the main indicators of product quality is seam strength, which depends on different technical-technological parameters: type of fabrics, type and thread count, needle size, stitch type, stitch density, seam type, etc. Seam strength is usually determined experimentally by defining the force that the seam can endure. Defining breaking force and breaking elongation is based on force and elongation measurements when the seam is subjected to a constant loading. The methods used for testing seam strength are based on thread slippage or breakage in the seam. According to tt. Coats method, seam breaking force is defined for 1 cm of seam length, i.e. by defining relative breaking force in cross direction in relation to seam line. Relative breaking force of the seam is calculated on the basis of average values of breaking force and seam length (i.e. test tube width) as follows:

$$F_{sr} = \frac{F}{b} \text{ (N/cm)}, \quad (7)$$

where: F – breaking force of test tube’s seam (N),
 b – test tube width for sewed sample (cm).

As the stitch density and breaking force of used thread also have great effect on breaking characteristics of seams, in this paper we introduce the parameter called “seam strength factor”, which can be determined according to the following equation:

$$f_p = F_T \cdot D_s \text{ (N/cm)}, \quad (8)$$

where: F_T – thread breaking force (N),
 D_s – stitch density (cm^{-1}).

For testing and control of fabric, threads and seam characteristics we used methods according to the following standards: BS EN 1049, BS ISO 7211-5, BS EN ISO 13934, BS EN ISO 2060, BS EN ISO 2061, BS EN ISO 2062, modified method according to the standard DIN 53857, ASTM D 1683, BS 3320, ISO 13935, ISO 4915, ISO 4916, ISO 139 and other additional methods. Mathematical statistics is used for data processing.

Materials used

Cotton fabric, used for shirt production, is used as basic material for seams. This fabric is in lean weave and has following characteristics: surface mass 130 g/m^2 , yarn count for warp and weft 29.5 tex, wire density per warp 28 cm^{-1} and per weft 16.2 cm^{-1} , breaking force in warp direction 488 N and in weft direction 267 N, breaking elongation in warp direction 6.8 % and in weft direction 12.7 %.

The sewing of samples was carried out by the following threads: T1-cotton mercerised thread, T2-cotton gauzed thread, T3-thread from mixture 60 % PES filament and 40% cotton fibres, T4-PES fibres thread, T5 and T6-threads from CEL fibres. The results of basic thread characteristics are shown in table 1.

Table 1. Indicators of used threads quality

Quality parameters	Sewing thread marks					
	T1	T2	T3	T4	T5	T6
Count (tex)	10.3 x 3	10.2 x 3	13.2 x 2	9.8 x 3	13.5 x 2	16.2 x 2
Piecing at twisting (m ⁻¹)	819	905	991	953	618	441
Breaking force (cN)	849	750	862	948	395	566
Relative breaking force (cN/tex)	27.47	24.51	32.65	32.24	14.63	17.47
Breakage work (cN·cm)	1158	1036	3656	2760	2258	2978
Elongation at break (%)	5.20	6.56	19.70	10.00	17.60	16.20
Breaking force of thread in the loop (cN)	1321	1397	1191	1401	574	828
Elongation at break of thread in the loop (%)	5.00	6.20	14.10	10.00	10.40	10.40

Used seam and stitch types

Pieces of fabrics were joined by seam (mark 1.01.01), stitch type 301 and 401 (according to ISO 4916 and ISO 4915), which are more used in practice.

Used sewing machines

Sewing process was carried out on sewing machines made by company Pfaff, class 483/BS (for stitch type 301) and class 5487/BS (for stitch type 401) with maximum speed of 2500 min⁻¹. Used sewing needles were 90 needle size with normal point.

Preparation of seam samples

Fabric samples are cut into 250 x 200 mm pieces and laid overlapping each other (face to face). Then, they are joined at longer sides (figure 3a). Two test tubes (70 mm width) are taken from the middle of these samples (Figure 3b) in order to prevent speed changes at the beginning and at the end of sewing. The final shape of the test tube is defined when we cut near the seam from both sides at about 50mm length (Figure 3c).

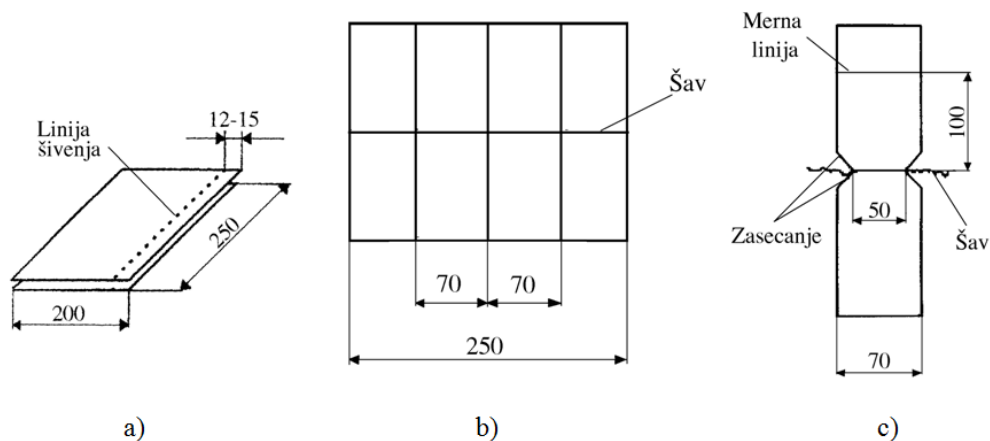


Fig. 3. Preparation of samples for testing seam strength (all measures in mm)

Climate conditions under which testing carried out are the same as the standard conditions. All samples were brought to standard condition in order to be tested in the same conditions.

Equipment for testing mechanical characteristics of threads, fabrics and seams

Dynamometer Uster Tensorapid 4 was used for defining breaking characteristics of sewing threads and Zwick/Roell Z010 was used for fabrics and seams. These two had uniform speed of mobile clamps.

3. Results and discussion

Sewing thread and stitch density are very important parameters as they have great influence on seam characteristics. Mechanical characteristics of sewed seams depend mainly on mechanical characteristics of thread and stitch density and one of them is breaking force. As far as sewing process is concerned, it is very important to project seam breaking force in relation to future usage of garment products. In order to do that, numerous measurements of seam breaking forces were carried out. It was done in order to compare those values to projected ones.

Results of testing seam breaking forces, i.e. relative breaking forces, seam strength factors and correction coefficients are shown in tables 2 to 5.

Table 2. Relative seam breaking forces, strength factors and i correction coefficient at sewing line in weft direction stitch type 301, stitch density from 2.41 cm⁻¹ to 8.69 cm⁻¹

	Relative seam breaking force F_{sr} (N/cm)	Seam strength factor f_p (N/cm)	$k = \frac{F_{sr}}{f_p}$
T1	21	20.4609	1.02635
	24.2	21.9042	1.10481
	25.4	22.5834	1.12472
	26	24.0267	1.08213
	26.4	25.6398	1.02965
	27	27.8472	0.96958
	27.2	29.4603	0.92328
	27.6	29.7999	0.92618
	28.6	32.1771	0.88883
	30.8	33.8751	0.90922
	30.6	34.2147	0.89435
	33.4	36.4221	0.91703
	35.6	40.752	0.87358
	37.8	44.4027	0.8513
	38.8	46.3554	0.83701
	39.2	48.4779	0.80862
46	54.7605	0.84002	
47	59.3451	0.79198	
54.8	63.8448	0.85833	
58.2	73.0989	0.79618	
T2	24	24.975	0.96096
	25.2	28.425	0.88654
	32.2	36.075	0.89258
	37.2	42.825	0.86865
	52	64.125	0.81092
T3	30.6	28.7046	1.06603
	38	33.3594	1.13911
	42.2	39.9106	1.05736
	46.6	50.427	0.92411
	59.8	74.9078	0.79831
T4	37.2	31.5684	1.17839
	40	36.024	1.11037
	44.8	45.1248	0.9928
	50.8	53.8464	0.94342
	62.2	81.7176	0.76116
T5	11.6	12.9165	0.89808
	14	14.7335	0.95022

	16.4	18.9995	0.86318
	17.8	22.9495	0.77562
	25.8	33.7725	0.76394
T6	16.4	18.5082	0.88609
	18.2	21.6778	0.83957
	22.4	27.6774	0.80932
	25.6	32.3186	0.79211
	29.8	48.393	0.61579

Table 3. Relative seam breaking forces, strength factors and i correction coefficient at sewing line in warp direction stitch type 301, stitch density from 2.38 cm⁻¹ to 5.71 cm⁻¹

Relative seam breaking force F_{sr} (N/cm)	Seam strength factor f_p (N/cm)	$k = \frac{F_{sr}}{f_p}$
21	20.2062	1.03928
21.2	21.7344	0.97541
21.8	22.923	0.95101
22	24.0267	0.91565
23	26.8284	0.8573
23.2	27.2529	0.85129
26.2	28.1019	0.93232
26.2	29.1207	0.8997
26.4	32.262	0.8183
27	33.7053	0.80106
28.6	34.1298	0.83798
28.8	35.8278	0.80385
31.4	24.975	1.25726
32.8	28.725	1.14186
40	36.075	1.1088
47.6	42.825	1.1115
36.6	28.5322	1.28276
43	32.756	1.31274
46.2	41.4622	1.11427
57	49.2202	1.15806
39.2	31.0944	1.26068
44.4	35.3604	1.25564
47.8	44.6508	1.07053
60	53.8464	1.11428
13	12.956	1.0034
14.2	14.8915	0.95356
19.8	18.881	1.04867
21.8	22.436	0.97165
20	18.5082	1.0806
22	21.3382	1.03101
28.8	27.6208	1.04269
32.4	32.3186	1.00252

Table 4. Relative seam breaking forces, strength factors and i correction coefficient at sewing line in weft direction stitch type 401, stitch type from 2.89 cm⁻¹ to 7.19 cm⁻¹

	Relative seam breaking force F_{sr} (N/cm)	Seam strength factor f_p (N/cm)	$k = \frac{F_{sr}}{f_p}$
	26.8	24.5361	1.09227
	27	24.7908	1.08911
	27.2	24.8757	1.09344
	29.2	24.9606	1.16984
	30	26.9133	1.11469
	32.4	28.1019	1.15295

	32.8	28.2717	1.16017
	33.6	30.9036	1.08725
	37.6	35.8278	1.04946
	41.2	38.6295	1.06654
	43.4	42.45	1.02238
	46	46.8648	0.98155
	47	51.4494	0.91352
	50.8	52.3833	0.96977
	57.8	59.7696	0.96705
T2	31.4	23.7	1.32489
	32.8	27.075	1.21145
	40	34.275	1.16703
	47.6	41.625	1.14354
	54	53.925	1.00139
T3	36.6	27.4116	1.3352
	43	31.3768	1.37044
	46.2	39.221	1.17794
	57	46.8066	1.21778
	63.4	60.6848	1.04474
T4	39.2	29.7672	1.31689
	44.4	33.8436	1.31192
	47.8	43.7028	1.09375
	60	50.4336	1.18968
	64.2	66.7392	0.96195
T5	13	12.324	1.05485
	14.2	14.062	1.00981
	19.8	17.933	1.10411
	21.8	21.4485	1.01639
	27.8	27.6105	1.00686
T6	20	17.8856	1.11822
	22	20.2062	1.08877
	28.8	25.6964	1.12078
	32.4	31.2432	1.03703
	39.4	38.9974	1.01032

Table 5. Relative seam breaking forces, strength factors and i correction coefficient at sewing line in warp direction stitch type 401, stitch density from 2.79 cm^{-1} to 5.35 cm^{-1}

	Relative seam breaking force F_{sr} (N/cm)	Seam strength factor f_p (N/cm)	$k = \frac{F_{sr}}{f_p}$
T1	24.8	23.6871	1.04698
	25	23.8569	1.04791
	25.8	24.0267	1.07381
	28	26.319	1.06387
	28	26.7435	1.04698
	28.8	27.2529	1.05677
	30	29.2056	1.0272
	31	32.1771	0.96342
T2	27	23.175	1.16505
	29.2	26.325	1.10921
	31.6	33.825	0.93422
T3	29.8	26.2048	1.1372
	31	29.9114	1.03639
T4	30.2	28.8192	1.04791
	31.2	32.8956	0.94846
T5	11.8	12.008	0.98268
	13.4	13.667	0.98046
	16.2	17.5775	0.92163
	17.2	20.6585	0.83259
T6	19	17.263	1.10062
	20.2	19.7534	1.02261

	22.6	25.0172	0.90338
	27.2	30.281	0.89825

According to tables, pictures 4 and 5 show graphics that represent the way of changing relative seam breaking force from changing of seam strength factors with stitch type 301, and in pictures 6 and 7 with stitch type 401.

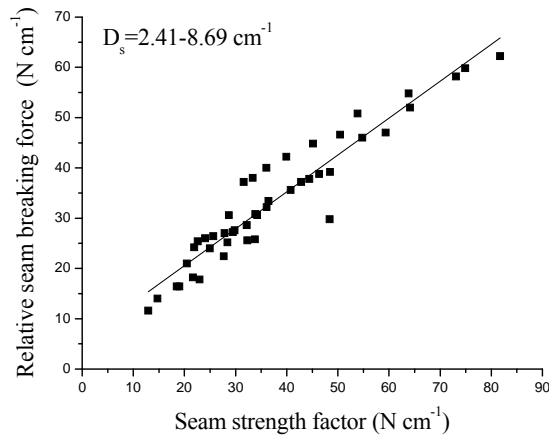


Fig. 4. Dependence of relative seam breaking force of seam strength factor for stitch type 301 and sewing line in weft direction.

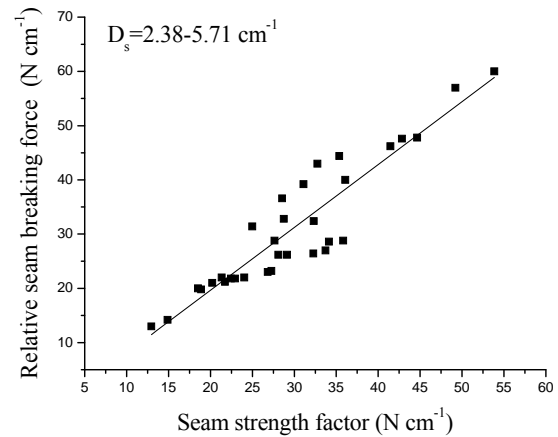


Fig. 5. Dependence of relative seam breaking force of seam strength factor for stitch type 301 and sewing line in warp direction.

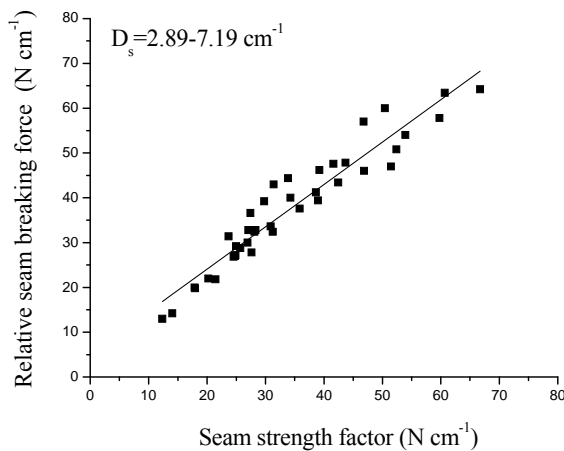


Fig. 6. Dependence of relative seam breaking force of seam strength factor for stitch type 401 and sewing line in weft direction.

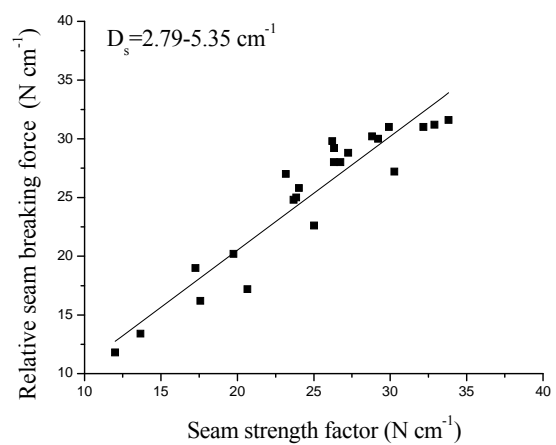


Fig. 7. Dependence of relative seam breaking force of seam strength factor for stitch type 401 and sewing line in warp direction.

Results that are shown in graphics are related to stated stitch densities, so changing of breaking force depending on stitch density gains approximately functional dependence. Higher levels of stitch densities cause violation of that dependence due to the fact that sewing needle often damage the fabric.

In that case, the equation for calculating seam strength factor ($f_p = F_T \cdot D_s$) and introducing correction coefficient (k) can enable using the equation for foreseeing relative seam breaking force. That equation will be as follows:

$$F_{sr} = k \cdot F_T \cdot D_s \quad (\text{N/cm}) \quad (9)$$

Experiments have justified the introduction of correction coefficient on the basis of statistical data processing (Table 6).

Table 6. Correction coefficient statistic

For data from tables and with a diagram	\bar{k}	SD	CV (%)	P_{gg}	$\bar{k} + P_{gg}$	$\bar{k} - P_{gg}$
table 2, figure 4	0.91195	0.11955	13.11	0.01782	0.92977	0.89413
table 3, figure 5	1.03143	0.14667	14.22	0.05081	1.08224	0.98062
table 4, figure 6	1.10914	0.1121	10.107	0.03474	1.14388	1.0744
table 5, figure 7	1.01511	0.08259	8.136	0.03375	1.04886	0.98136

4. CONCLUSION

Breaking characteristics of sewed seams depend on their structural solutions, as well as on technological conditions of the sewing process. Knowing mutual connectivity between structural and mechanical characteristics of seams can lead to appropriate projecting of those seams depending on their future usage.

On the basis of experimental results and theoretical assumptions, some real mathematical dependences were set. These dependences can be used for predicting breaking forces of sewed seams. Relative seam breaking force is presented as a function of breaking force for used sewing thread, stitch density and correction coefficient, which takes into account changes that occur as a result of dynamic load of materials that take part in the sewing process.

The recommended equation can be used for predicting seam breaking force. This should lead to simpler and improved technical preparation of garment production, material and energy saving.

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SINGLE-BATH COMBINED DYEING AND ANTIMICROBIAL FINISHING OF 100% POLYESTER YARNS

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Keywords: single-bath dyeing and finishing, polyester dyeing, antibacterial finishing

Abstract: *100% polyester yarns were dyed with C.I. Disperse Blue 165 and finished with an antimicrobial agent, namely Microfresh Liquid formulation 9200-200 (DyStar), in the same bath. After the combined process, a reductive clearing was applied to half of the material. The fastness of the antimicrobial performance of the dyed and finished yarns was evaluated in accordance with AATCC 61-2006. The antimicrobial effects were given as % reduction of bacteria and the % reduction values were calculated in accordance with the AATCC 100-2004. Comparisons of the antimicrobial effect of untreated materials were carried out with the dyed and reductive cleared, and the dyed and finished materials. The results show that dyeing and finishing with antimicrobial agents can be performed successfully in a single bath. The color yield, dyeing fastness, dyeing repeatability properties were investigated.*

1. INTRODUCTION

In recent years, the antimicrobial finishes are widely applied to textile materials because of increasing public awareness of hygiene and potentially harmful effects of micro-organisms. The chlorine containing organic products as well as the inorganic products based on silver and quaternary ammonium salts are employed as antimicrobial agents¹⁻¹⁸. The application methods of antimicrobial finishing agents include spraying, padding, exhaustion, plasma and coating techniques. On the other hand, very recently “inherent” antimicrobial fibres are produced by adding the antimicrobial agents into the polymer. The application of the antimicrobial agent during dyeing is also possible.

2. EXPERIMENTAL PART

2.1 Aim of the Work

The aim of this work is to apply an antimicrobial finish to 100% polyester yarns in hanks during dyeing and the evaluation of the antimicrobial and color properties of the treated materials.

2.2 Material

In this work, 300 denier/72 filaments 100% polyester yarns were used throughout the experimental work. The samples were prepared and treated in hanks.

2.3 Equipment Used in the Experimental Work

The exhaustion of the antimicrobial finish at the dyeing stage was carried out in Roaches HT laboratory dyeing machine.

2.4 Type of the Bacteria Used in the Work

In this work, three types of bacteria, namely, Staphylococcus Aureus, Escherichia Coli and Bacillus Sublitis were used.

2.5 Antimicrobial Finish, Dyes and Auxiliaries

2% o.w.f. Microfresh Liquid Formulation 9200-200 (DyStar) as an antimicrobial agent and C.I. Disperse Blue 165 (Dianix Blue S-2R) were used in dyeings. 2 g/L Dispersogen P Liq. (Clariant) was used in each dye bath as a dispersing agent, and the pH of the bath was adjusted with acetic acid.

10 g samples were dyed at 1% colour strength and treated with the antimicrobial agent simultaneously in the dyeing. The liquor ratio was 20:1.

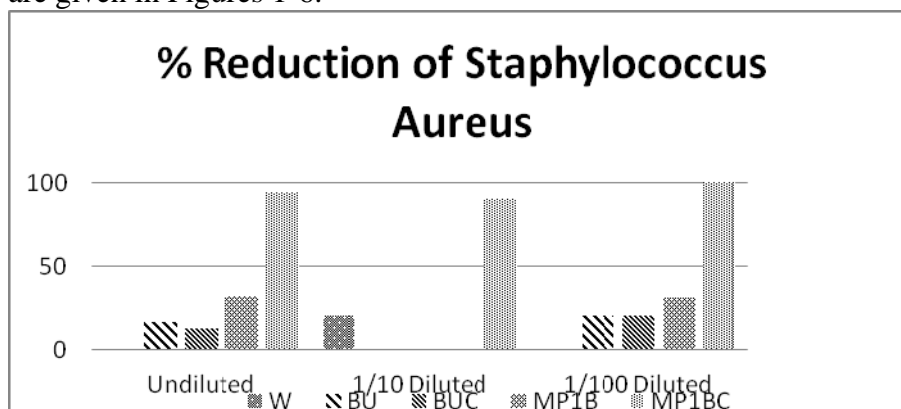
The simultaneously dyeing and antimicrobial finishing treatment was commenced at 40°C, after 25 minutes, the temperature was raised to 70°C in 5 minutes at a heating rate of 5°C/min and later at a heating rate of 1.5°C/min. to 130°C in 40 minutes. The dyeing and finishing were carried out at this temperature for 20 minutes. The bath was later cooled down at a cooling rate of 3.5°C/minutes to 70°C in 15 minutes and eventually to 25°C. A reduction clearing was given to the dyed materials.

2.6 Evaluation of the Antibacterial Performance

AATCC 100-2004 standard was used to evaluate the antibacterial performance and the antibacterial finished samples were given repeated washing tests in accordance with AATCC 61-2006 (Method 1A) to evaluate the fastness of the effect.

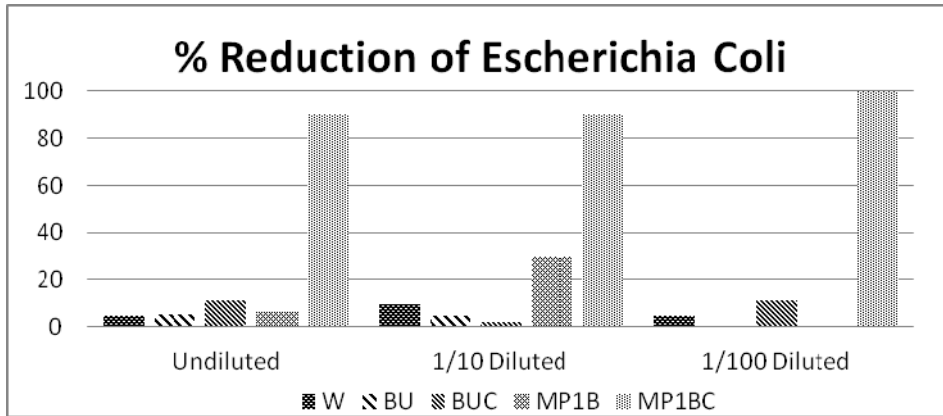
3. RESULTS AND DISCUSSIONS

The results are given in Figures 1-6.



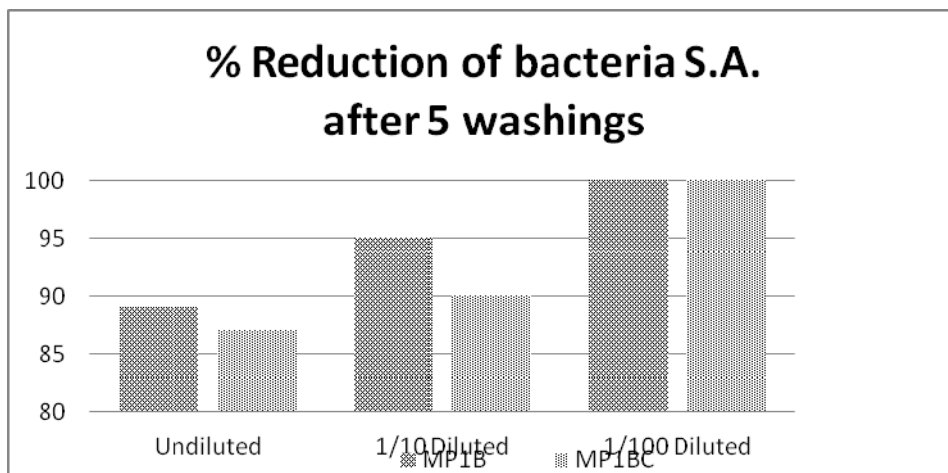
Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 1: % Reduction of Staphylococcus Aureus.



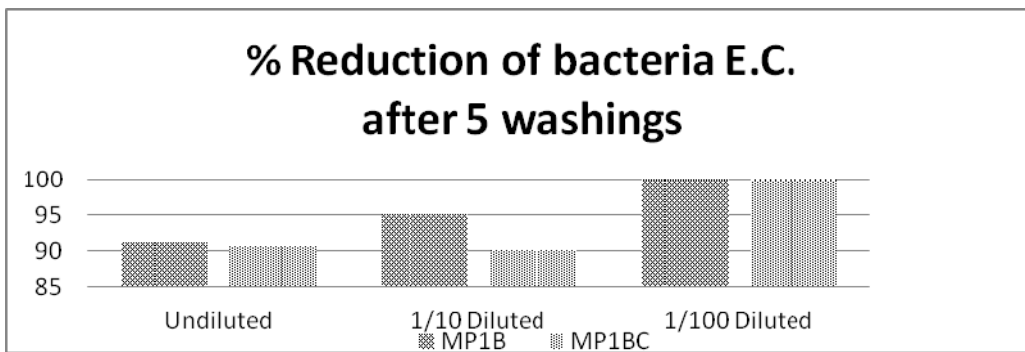
Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 2: % Reduction of Escherichia Coli.



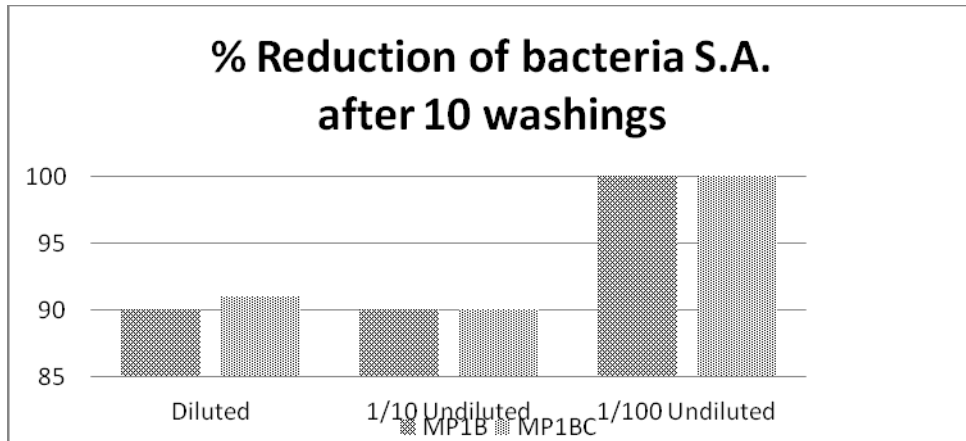
Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 3: % Reduction of Staphylococcus Aureus after 5 washings.



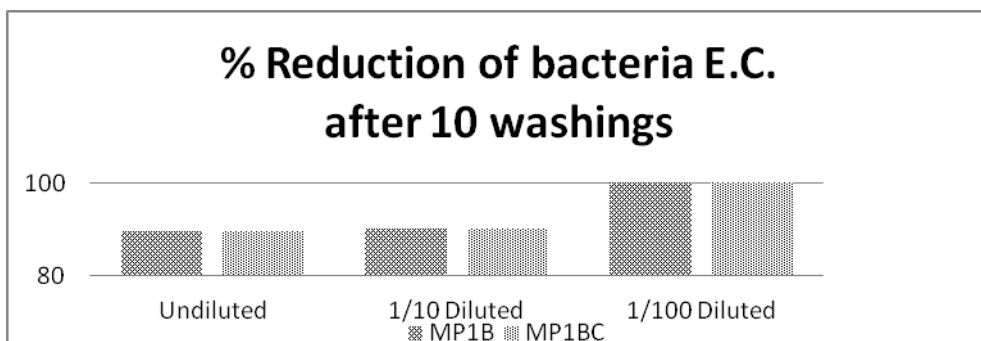
Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 4: % Reduction of Escherichia Coli after 5 washings.



Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 5: % Reduction of Staphylococcus Aureus after 10 washings.



Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

Figure 4: % Reduction of Escherichia Coli after 10 washings.

The CIELab values of the treated and reductive cleared materials were given in Table 1. The colour fastness values of the materials were “4” or “4-5” in some samples. The antimicrobial finish had little adverse effect on the colour values of the samples.

Table 1: CIELab values of reductive cleared materials

Code of the Material	CIELab Values							
	L*	a*	b*	C*	h	X	Y	Z
W	89.24	-0.21	2.23	2.24	95.43	70.70	74.67	77.21
BUC	31.25	8.08	-42.35	43.11	280.81	7.20	6.76	25.46
MP1BC	34.38	6.14	-42.84	43.28	278.15	8.44	8.19	29.26

Key: (W) White yarn, (U) Untreated with microbial agent, (C) Reductive cleared yarn, (M) Material treated with antimicrobial agent, (B) Dyed with Disperse Blue 165, (P1) Simultaneously dyed and finished material.

4. CONCLUSIONS

The antibacterial agent and the process used in this work were found to be effective against the bacteria Staphylococcus Aureus and the bacteria Escherichia Coli, but not effective against Bacillus Sublitis. The antibacterial effect is fast to repeated washings, and the reduction clearing process had no adverse effect on the treatment.

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