Egypt.J.Chem. **Vol. 63**, No.9. pp. 3367- 3380 (2020)

Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Surface Modification of Polyester Fabric Using Microwave Irradiation to Minimize Pollution in Textile Industry via Optimizing Energy and Time

R. S. Rizk*, W. A. El Sayed, N. S. Ashour, Omnia Kh. Ahmed
Faculty of Women for Arts, Science and Education, Ain Shams University, Cairo, Egypt.

POLYESTER surface fabric was modified using Sodium Hydroxide solution with different concentrations. The wettability of the fabric was enhanced. The modification was carried out using two different techniques; conventional and microwave irradiation. The conditions of both techniques were studied. The new modified polyester fabric was further modified using Zinc Oxide in order to add value to the modified fabric. The add on characters are; inhibition of bacteria growth of the surface, protection from ultraviolet radiation as well as enhanced the dyeability of the fabric. Both different techniques also used. The properties of the new modified fabric were studied. Microwave irradiation techniques used showed the best results of different properties. Minimizing the energy and time of the treatments were fulfilled.

Keywords: Microwave, Alkaline hydrolysis, Polyester, Wettability, Antibacterial, Zinc Oxide, UPF.

Introduction

Polyester fiber has occupied the leading position among the three major synthetics fibers; due to its specific advantages such as high strength, abrasion resistance, wash and wear, and wrinkle-free characteristics. On the other hand, it has some disadvantages as low moisture regains and poor wettability i.e. it is hydrophobic and oleophilic. These problems can overcome by alkaline hydrolysis, which converts hydrophobic polyester into hydrophilic [1-4].

Due to low its hydrophilicity, polyester is usually dyed with disperse dyes at high temperatures and high pressures. To improve the dyeing properties, many researchers have tried different methods to solve these problems [2].

Microwave irradiation is an electromagnetic wave region between infrared waves and radio waves (0.3-30 GHz) in the electromagnetic spectrum. Microwave irradiation become an important feature in the textile industry at recent years; it was described as green chemistry which refers to the design of chemical products and the processes that eliminate the pollution and hazardous to human health, so microwave synthesis is considered as an important approach toward green chemistry [5, 6].

Textile is one of the industries that use massive water and energy, so in recent researches, microwave irradiation was showed great development in textile finishing especially in surface modification of polyester fabric and enhancement take up in dye process which consumes the time and energy [2, 5, 6]

On the other hand, Zinc Oxide has attracted wide interest in recent years due to its properties and non-toxic which considered as green synthesis and has been approved as a safe material from the United States Food and Drug Administration [7, 8]. Zinc oxide can be considered as multifunctional materials due to its unique physical and chemical properties which lead to use it in protection products due to its property against bacteria and the ability to absorb (UV-A, UV-B) radiation, so Zinc oxide known as UV blocker or absorber [8, 9].

*Corresponding author e-mail: Rehab.metwally@women.asu.edu.eg
Received 21/4/2020; Accepted 13/5/2020
DOI: 10.21608/ejchem.2020.27949.2601

At this work, surface modification of polyester was done using sodium hydroxide and zinc oxide. Different factors were studied using conventional and microwave techniques. The effects of the treatments on different properties of the modified fabric such as antibacterial, U.V protection, and dyeability were investigated. These add on properties raise the polyester rank as well as minimizing pollution of textile industries via reducing energy and time of different processes as a result of using microwave irradiation techniques.

Experimental

Materials

Fabric

Polyester fabric 100% plain weave) 120 g/m2), 65 picks/inch, and 163 ends/inch was purchased from Masr Spinning & Weaving El-Mahallaa El-Kobra Company, Egypt

Chemicals and equipment

All chemicals and equipment were of laboratory grade reagents.

Dyes

Disperse dye Dianix Blue E-R 150% (C.I. Disperse Blue 56) was kindly supplied by "Dystar Company", Cairo, Egypt.

Microorganisms

Staphylococcus aureus (S. aureus) as a gram-positive and Escherichia coli (E. coli) as gram-negative were supplied from the Faculty of Agriculture- Ain Shams University, Egypt.

Media

Suitable broth/ agar media are Nutrient which contains: Peptone (5 g/L) and beef extract (3 g/L)[10] were supplied from Al - Gomhoria Company for medicines and medical supplies, Egypt.

Methods

Finishing technique

Hydrolysis of polyester fabric using sodium hydroxide via microwave irradiation technique.

The polyester fabrics were impregnated in treatment baths containing (3, 6, 9, 12, and 15% o.w.f.) NaOH at L: R (1:30-1:70 o.w.f.). Then the sample squeezed using laboratory padder to get (80, 90, 100, 110, and 120%) wet pick up. The sample raped in a plastic sheet and put it in the microwave at different power (low, med. low, med., med. high and high) for (1, 1.5, 2, 2.5, and 3 min.). The polyester samples were acidified using acetic acid with different conc. (3, 6, 9, 12 and 15%).

Hydrolysis of polyester fabric using sodium hydroxide via conventional technique.

The polyester fabrics were impregnated in treatment baths containing (3, 6, 9, 12, and 15% o.w.f.) NaOH with L: R (1:30-1:70 o.w.f.). The samples squeezed using laboratory padder to get an (80, 90, 100, 110 and 120%) wet pick up The samples were putting in a plastic sheet and kept at (20, 30, 40, 50 and 60°C) for (4, 6, 8, 12 and 24 hour), then acidified with different concentrations (3, 6, 9, 12, and 15%) of acetic acid.

Treatment of polyester fabrics with zinc oxide via microwave technique

Hydrolyzed as well as untreated polyester fabrics were impregnated in a solution of different concentration of zinc oxide (1-5 % o.w.f) dissolved in 4% acetic acid, then fixed at different power(low, med. low, med., med. high and high) for different times (5,10,15, 20, 25 and 30 min.) at microwave oven. The treated fabrics dried in an ambient condition, then cured at 200°C for 3 min. and finally rinsed.

Treatment of hydrolyzed and untreated polyester fabrics with zinc oxide via conventional technique.

Hydrolyzed as well as untreated polyester fabrics were impregnated in a different concentration of zinc oxide solution (1,2,4,6 and 8 % o.w.f.) dissolved in 4% acetic acid for 5 min. The treated fabrics dried in an ambient condition, then cured at 120°C for 6 min., rinsed and soaped with nonionic detergent (2g/L).

Dyeing of polyester and hydrolyzed ZnO treated polyester fabrics with disperses dye

Dyeing using microwave technique

The untreated, untreated/ZnO, hydrolyzed, and hydrolyzed/ZnO polyester fabrics were dyed using 2%dye shade (C.I. Disperse Blue 56), 15g/L carrier, 5ml/L acetic acid to adjust the PH for 4-5 in presence of 2-3g/L dispersing agent. The dyeing was carried out at different microwave power (low, med. low, med., med. high and high) for (5, 10, 15, 20, 25, and 30 min.). The samples were rinsed, and reduction cleaned with detergent 2g/L at 60°C for 20 min.

Dyeing with conventional technique

The untreated, untreated/ZnO, hydrolyzed, and hydrolyzed/ZnO polyester fabrics were dyed using a 2% dye shade (C.I. Disperse Blue 56), 15g/L carrier, 5ml/L acetic acid to adjust the PH for 4-5 in presence of 2-3g/L dispersing agent. The temperature of the dyeing bath was raised gradually, kept at 90°C for 60 min., and then lowered to 60°C. Reduction cleaning was done if required, rinsed well and dried.

Test methods

Physico-mechanical properties evaluation

Determination of wettability

The Water wettability test was determined using AATCC Test Method 79-2000[11].

Determination of tensile strength

Tensile strength and extension at break were determined using ASTM D 5035 [12]

Determination of tearing strength

Tearing strength was determined using ASTM D 1424.[13]

Colour measurements

Colour strength

The color strength was determined by measurement of the K/S value of the dyed samples using Mini ScanTM XE Hunter-lab Universal Software, which determined by the Kubelka–Munk equation:

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

Where R is a fraction of light reflected at a wavelength of maximum absorbance or minimum reflectance, K is the absorption coefficient and S is the scattering coefficient[14].

Fastness properties measurements

Light fastness

The light fastness of dyed fabrics was evaluated according to -ISO 105-B02 test method [15].

Wash fastness

The wash fastness of dyed fabrics was evaluated according to ISO 105-C06 test method [16].

Perspiration fastness

The colorfastness to the perspiration of dyed fabrics was determined according to ISO 105-E04 test method [17]

Antibacterial evaluation:

The AATCC 100 or TM 100 is an antibacterial count test method used to assess textiles treated with antimicrobial products as a part of the finished textile coating. The percent reduction of bacteria was calculated using the following formula 100 (B - A)/B = R where: R = % reduction where A = the number of bacteria recovered from the inoculated treated test specimen swatches in the jar incubated over the desired contact period B = the number of bacteria recovered from the inoculated treated test specimen swatches in the jar immediately after inoculation (at 0 contact time)[10].

Ultraviolet protection factor (UPF) evaluation

UPF was determined according to AATCC 183-2010 standard test method

$$UPF = \frac{\sum_{280\,nm}^{400\,nm} E\lambda \times S\lambda \times \Delta\lambda}{\sum_{280}^{400} E\lambda \times S\lambda \times T\lambda \times \Delta\lambda}$$

where: $E\lambda$ = relative erythemal spectral effectiveness, $S\lambda$ = solar spectral irradiance, $T\lambda$ = average spectral transmittance of the specimen (measured) $\Delta\lambda$ = measured wavelength interval (nm) [18]

Durability test

The optimized polyester fabric samples were washed for (5 and 30) washing cycles according to the AATCC test method [19].

Result and Discussion

To get the best-modified surface of polyester fabric to enhance, wettability, Drapability, hand, antibacterial, anti UV harmful effect as well as dyeability, the following results obtained and discussed, using conventional and microwave irradiation techniques.

Effect of treatment time with sodium hydroxide on the polyester fabric wettability

The effect of time of the treatment was shown in figure (1, 2). Generally, the treatment of fabrics with sodium hydroxide leads to the

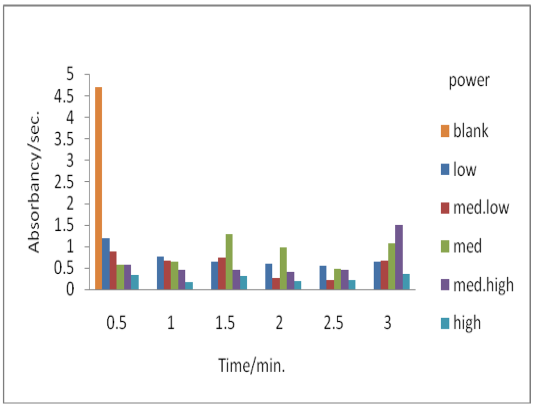


Fig. 1. Effect of the treatment time on wettability of polyester fabric using microwave technique.

Condition: NaOH conc. 3% o.w.f.; L: R 1:50 o.w.f.; wet pick up 80%; power low, med. low, med., med. high and high; time/ min. 0.5, 1, 1.5, 2, 2.5 and 3.

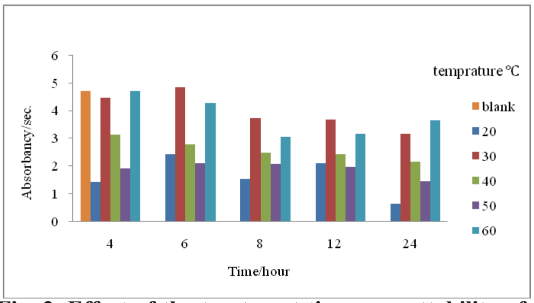


Fig. 2. Effect of the treatment time on wettability of polyester fabric using conventional technique.

Condition: NaOH conc. 3% o.w.f.; L: R 1:50 o.w.f.; wet pick up 80%; temp. °C 20, 30, 40, 50 and 60; time / hr.4, 6, 8, 12 and 24.

decrease of fiber diameter and enhancing their wettability[20].

In figures (1, 2) It was observed that by increasing the treatment time the wettability time decreased regardless of the temperature used. These may be attributed to the formation of hydrophilic groups as -OH and -COOH due to hydrolysis [4, 21].

The microwave technique shows the best results than conventional technique because of microwave irradiation causes rapid heating in short reaction time [22].

The effect of sodium hydroxide concentration (conc.) on the wettability of polyester

Figures (3, 4) show an increase in sodium hydroxide concentration leads to a decrease in wettability time regardless of the temperature used. The enhancement in wettability is due to increases in hydrolysis percent of polyester fabrics. Using the microwave technique shows the best result because of the acceleration of treatment time, this leads to absorb the irradiation energy directly, speeding up the hydrolysis of the

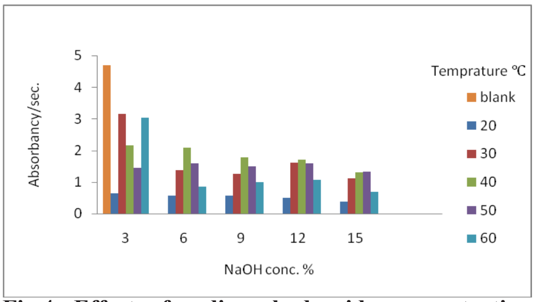
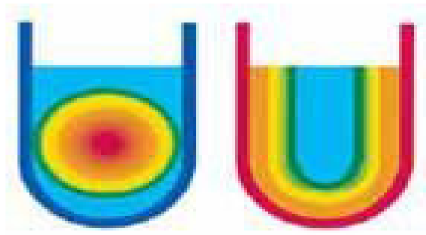


Fig.4. Effect of sodium hydroxide concentration on wettability of polyester fabric using conventional technique.

Condition: NaOH conc. 3, 6, 9, 12 and 15%o.w.f.; L: R 1:50 o.w.f.; wet pick up 80%; temp. °C 20, 30, 40, 50 for 24 hr.; 60 for 8 hr.



Microwave heating conventional heating

Fig.5. Microwave heating and conventional heat dissipation [5].

polyester surface [2]. Whereas in the conventional technique the outer wall heated first, then penetrate to the second layer and finally moves to the center as illustrated in (Figure 5)[2, 5].

The effect of pick-up percent of sodium hydroxide solution on the wettability of polyester

Figures (6,7) show decreasing in wettability time by increasing the wet pick up % regardless of the temperature used. This may be attributed to increasing the concentration of NaOH which increasing the percent of hydrolysis of polyester

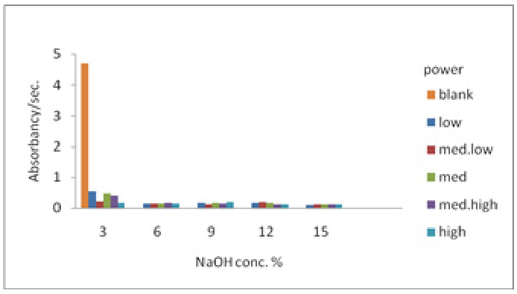


Fig. 3. Effect of sodium hydroxide concentration on wettability of polyester fabric using microwave technique.

Condition: NaOH conc. 3, 6, 9, 12 and 15% o.w.f.; L: R 1:50 o.w.f.; wet pick up80%; power low, med. low and med. for 2.5 min, med. high for 2 min. and high for 1 min.

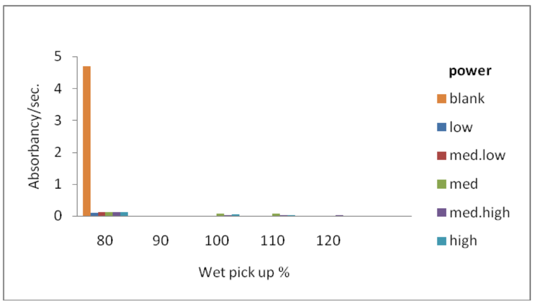


Fig. 6. Effect of wet pick-up percent on wettability of polyester fabric using microwave technique.

Condition: NaOH conc. 9, 12 and 15% o.w.f.; L: R 1:50 o.w.f.; wet pick up 80, 90, 100, 110 and 120%; power low, med. low and med. for 2.5 min, med. high for 2 min. and high for 1 min.

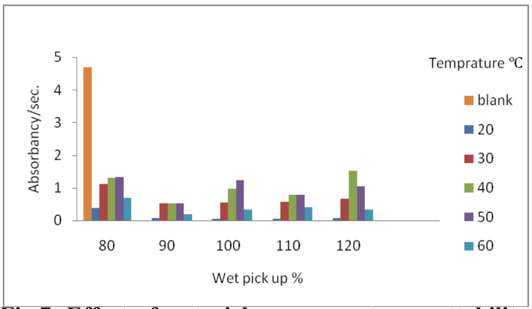


Fig.7. Effect of wet pick-up percent on wettability of polyester fabric using conventional technique.

Condition: NaOH conc. 15% o.w.f.; L: R 1:50 o.w.f.; wet pick up % 80, 90, 100, 110, 120; temp. °C 20, 30, 40, 50 for 24 hr., 60 for 8 hr.

which leads, in turn, enhanced the wettability[23]. The microwave heating rapidly degrades the polyester as compared to the conventional heating, due to the effect of the irradiation energy of microwave [2, 6, 22] .

The effect of the treatment liquor ratio of on the wettability of polyester fabric

Figure (8) shows an increase in liquor ratio using conventional technique leads to a decrease of wettability time; this may be attributed to an increase in the concentration of sodium hydroxide which increasing the hydrolysis rate of polyester.

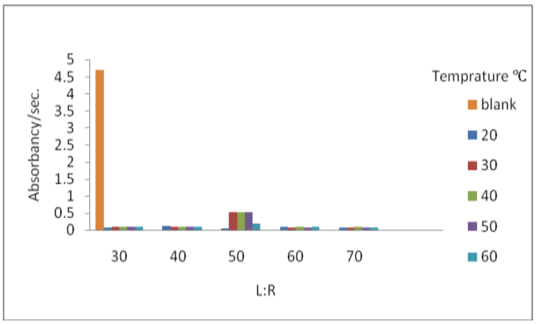


Fig.8. Effect of liquor ratio of the treatment on wettability of polyester fabric using conventional technique.

Condition: NaOH conc. 15% o.w.f.; L: R 1:30, 1:40, 1:50, 1:60, 1:70 o.w.f.; wet pick up 90%; temp.°C 20, 30,40 and 50 for 24 hr., 60 for 8 hr.

The lowest liquor ratio conc. (1:30) showed an excellent result (100 % wettability zero sec.) even at low microwave temperature using NaOH (15%) at 2.5 minute.

The variety in liquor ratio does not have a huge effect on wettability on polyester fabric but was preferred using the lowest possible liquor ratio as possible to minimize the pollution of the environment [24] .

The effect of hydrolysis on the polyester fabric strength

Table (1, 2) the loss is may due to the effect of

TABLE 1.The effect of hydrolysis of polyester fabrics with NaOH on their tensile and the tear strength using microwave technique.

Property	Untreated fabric	Microwave temp.				
		low	med. low	med	med. high	high
Tensile strength in warp (g/5cm)	83.3	79	62	53	50.5	44
Warp elongation%	64.3	64.3	45	50	48.5	44
Tensile strength in weft (Kg/5cm)	67.6	67.5	43.5	49.5	54	53.5
Weft elongation%	43	42	33.5	33.3	32.5	30
Tear strength in warp (gm.)	3300	1800	1600	1800	2000	2350
Tear strength in weft (gm.)	2350	2033	2033	2000	3166	3300

Condition: NaOH conc. 9, 12 and 15% o.w.f.; L: R 1:30 o.w.f.; wet pick up 90%; power low, med. low and med. for 2.5 min, med. high for 2 min. and high for 1 min.

TABLE 2. The effect of hydrolysis of polyester fabrics with NaOH on their tensile and the tear strength using conventional technique.

Property	Untreated fabric	Conventional temp./°C				
		20	30	40	50	60
Tensile strength in warp (Kg/5cm)	83.3	85	72.5	72.6	57.6	53.5
Warp elongation%	64.3	52.6	49	47	47.3	43
Tensile strength in weft (Kg/5cm)	67.6	71	63	63	57.5	57
Weft elongation%	43	34	33.3	33.5	34.3	34
Tear strength in warp (gm.)	3300	2433	2200	3000	1750	2650
Tear strength in weft (gm.)	2350	2550	2100	2400	2600	2450

Condition: NaOH conc. 15% o.w.f.; L: R 1:30 o.w.f.; wet pick up 90%; temp°C 20, 30, 40 and 50 for 24 hr., 60 for 8 hr.

the energy of microwave which causes a random motion of the particles of NaOH generating heat and speed of motion leading to bond fission i.e. hydrolysis occur causing decreases in tensile and tear strength [2, 4-6].

Effect of the treatment of hydrolyzed and untreated polyester fabric with Zinc Oxide on some of its properties.

Effect of treatment with Zinc Oxide on the wettability of hydrolyzed and untreated polyester fabric using microwave technique

Tables (3, 4, 5, 6, and 7) show an increase in the wettability time of ZnO treated polyester at low power rather than the higher one regardless of concentration. This may be attributed to the particle size of ZnO, which accumulate at a higher temperature so they have a difficult in penetration through the fine macro pores structure of the fabric, as well as the area of contact between the ZnO particles and the surface of the fabric is retracted [25, 26] as shown in figure (9, 10).

Tables (3, 4, 5, 6, and 7) showed the time of wettability increased by increasing ZnO concentration which causes a surface roughness. A surface roughness which acts as a barrier opposed the water penetration. As well as the action of a particle of ZnO, which agglomerate by increasing the temperature as shown in figure (9, 10)[25, 26]

Effect of treatment with Zinc Oxide on the wettability of untreated and hydrolyzed polyester fabric using conventional technique

Table (8) shows a slight increase in wettability by increasing ZnO concentration; the increase of ZnO conc. the wettability decreased. This may be due to an aggumilation of ZnO particles, so the difficulty of penetration process through the fine micro pores structure of the fabric. So, the aggumelate particles easily removed by washing [26].

The effect of surface modification of polyester fabric on different properties

The effect of the modified surface of polyester fabric on dyeability, fastness properties, antibacterial, protection against UV irradiation as well as some mechanical properties as tear and tensile strength were studied, using the fabric showed the optimum condition of the treatment.

Effect of Sodium Hydroxide and Zinc Oxide treatment of polyester fabric on Colour Strength using Disperse Blue 56

The color strength(K/S) of the untreated polyester fabric shows result lower than treatment samples even with microwave or conventional techniques, as shown in table (9)the alkali treatment opens the structure of polyester causes an increase in OH- and COOH- groups, i.e. increasing the wettability of the fabric and ease the diffusion of the dye molecules. The microwave technique shows the best result than the conventional one. The irradiation energy of

TABLE3. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric at low power using microwave technique.

ZnO con-centration g/100ml	Time/min. 0		5		10		15		20		25		30	
	Fabrics													
	Untreated*	**NaOH***	**Untreated/ ZnO***	**NaOH/ ZnO***	**Untreated/ ZnO**	**NaOH/ ZnO**	**Untreated/ ZnO**	**NaOH/ ZnO**	**Untreated/ ZnO**	**NaOH/ ZnO**	**Untreat-ed/ ZnO**	**NaOH/ ZnO**	**Un-treated/ ZnO**	**NaOH /ZnO**
	Wettability/sec.													
1			6	0.98	8.56	4.2	9.67	3.69	7.16	2.04	5.48	7.68	7.46	4.7
2			4.66	3	8.12	14	12.5	5.94	15.12	7	12	23.5	16.5	4
3	4.7	zero	27.5	0.2	14.16	11.7	6.58	4.89	10.37	8.89	22.5	41.97	25	40.61
4			9.17	2.1min	9.95	3.11	25	19	13.4	23	28	3.31	31	3
5			1.2 min	14.75	29.52	4.5	39.9	3	33.89	4.08	27.87	15.1	2.28	43.9

Untreated=Untreated polyester fabric NaOH *= Hydrolyzed polyester using NaOH Untreated/ZnO *= untreated polyester fabric treated using ZnO NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO.Condition: power. low; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f..; time 2 min. Drip dry in ZnO; curing 200°C; curing time 3 min.

TABLE 4. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric at med. Low power using microwave technique.

ZnO concentration g/100ml	Time/min. 0		5		10		15		20		25		30	
	Fabrics													
	Untreated*	**NaOH***	**Untreat-ed/ ZnO**	**NaOH/ ZnO**	**Untreat-ed/Zn O**	**NaOH/Z nO**	**Untreated/ ZnO**	**NaOH/ ZnO**	**Untreated/ ZnO**	**NaOH/ ZnO**	**Untreat-ed/ ZnO**	**NaOH/ ZnO**	**Untreat-ed/ZnO**	**NaOH/ ZnO**
	Wettability/sec.													
1			12.2	1.18	13.47	1.54	15.37	1.51	19.76	2.8	22.68	2.8	24	2.2
2			8.22	0.89	9.1	1.61	15.88	1.7	23.44	1.17	23.24	1.67	25	2.33
3			9	2.07	28	2.51	29	3	31	4.6	29.65	1.48	32	5.2
4			31	3.15	23	3.9	50	2.25	25	7.88	25.5	1.97	29	5
5	4.7	zero	37.5	1.95	15	4.1	17.96	2	44	8	30	4.5	1.7 min.	5.23

Untreated=Untreated polyester fabric NaOH*= Hydrolyzed polyester using NaOH Untreated/ZnO *= untreated polyester fabric treated using ZnO NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO

Condition: power med. low; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f..; time 2 min. Drip dry in ZnO; curing 200°C; curing time 3 min

TABLE 5. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric at med. power using microwave technique.

ZnO concentration g/100ml	Time/min. 0		5		10		15		20		25		30	
	Fabrics													
	Untreated*	NaOH*	Untreated/ ZnO*	NaOH/ ZnO*	Untreated/ ZnO	NaOH/ ZnO	Untreated/ ZnO	NaOH/ ZnO	Untreated/ ZnO	NaOH/ ZnO	Untreated/ ZnO	NaOH/ ZnO	Untreat-ed/ ZnO	NaOH/ ZnO
	Wettability/sec.													
1			20.5	3.83	30	1.2	17	1.41	14	3.44	12	3.47	12.92	34
2			19.92	4.48	18.53	2.9	1.12 min.	1.69	41	1.22	16	1.49	13	2.15
3			12.92	7.16	20.5	2.98	25.5	4.1	19.97	2.44	42.29	2.27	46.35	3.11
4	4.7	zero	22.96	3.46	15.87	5.6	18	3.14	26.59	5.21	28	5.02	42	7
5			1.6 min	2.7	2.75 min.	1.89	40	4.72	38.58	5.68	28.22	11.9	28	8.37

Untreated=Untreated polyester fabric NaOH*= Hydrolyzed polyester using NaOH Untreated/ZnO *= untreated polyester fabric treated using ZnO NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO

Condition: power. med.; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f..; time 2 min. Drip dry in ZnO; curing 200 o; curing time 3 min

TABLE 6. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric at med. high power using microwave technique.

ZnO concentration g/100ml	Time/min. 0		5		10		15		20		25		30	
	Fabrics													
	Untreated*	NaOH*	Untreated /ZnO*	NaOH/ ZnO*	Untreated /ZnO	NaOH/ ZnO	Untreat-ed/ ZnO	NaOH/ ZnO	Untreated /ZnO	NaOH/ ZnO	Un-treated /ZnO	NaOH/ ZnO	Un-treated /ZnO	NaOH/ ZnO
	Wettability/sec.													
1			8.45	1.7	5.32	1.86	3	1.86	2.12	2.07	2	5.86	4.15	2.44
2			5.89	1.34	4.28	5.09	5	1.9	7.4	1.53	8.18	1.37	5.45	3.5
3			3.11	3.47	6.24	3.88	5.64	4.14	5.62	3	4.99	2.5	7.59	4.5
4	4.7	zero	10.34	2	10.09	3.52	10.48	6.45	7.13	1.26	8.83	1.7	10.21	4.53
5			7.64	2.14	7	1.4	13.46	3.17	4.26	1.58	3.03	1.58	14.66	2.25

Untreated=Untreated polyester fabric NaOH*= Hydrolyzed polyester using NaOH Untreated/ZnO *= untreated polyester fabric treated using ZnO NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO

Condition: power. Med. high; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f..; time 2 min. Drip dry in ZnO; curing 200°C; curing time 3 min.

TABLE 7. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric at high power using microwave technique.

ZnO concentration g/100ml	Time/min. 0		5		10		15		20		25		30	
	Fabrics													
	Untreated*	NaOH*	Untreated/ZnO*	NaOH/ZnO*	Untreated/ZnO	NaOH/ZnO	Untreated/ZnO	NaOH/ZnO	Untreated/ZnO	NaOH/ZnO	Untreated/ZnO	NaOH/ZnO	Untreated/ZnO	NaOH/ZnO
	Wettability/sec.													
1			13.96	0.81	14.52	0.9	15.24	1.17	18.46	1.27	24	1.87	25.37	2.17
2			19.5	0.81	26.66	1.8	36.06	1.26	27.62	1.29	18.38	1.32	14.97	1.38
3	4.7	zero	43.72	0.94	49.37	1.03	48.92	1.26	38	2.62	30.58	2.05	23.39	2.2
4			37.57	1.23	35.66	0.81	25.8	1.41	41.51	1.07	58	2.13	1.01 min.	0.94
5			1.12 min.	1.96	1.50 min.	2.06	1.26 min.	2.18	40.73	2.5	36	2.85	2.15 min.	1.7

Untreated=Untreated polyester fabric NaOH*= Hydrolyzed polyester using NaOH Untreated/ZnO *= untreated polyester fabric treated using ZnO NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO

Condition: power. high; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f.; time 2 min. Drip dry in ZnO; curing 200°C; curing time 3 min.

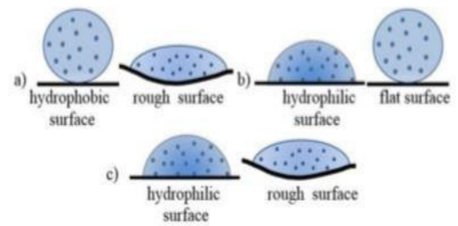


Fig. 9.A shape of drop on different textile surfaces [27].

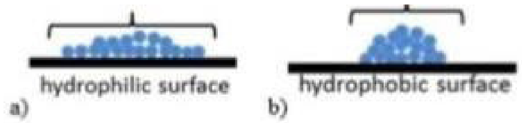


Fig. 10. ZnO particles on different textile surfaces [27].

TABLE 8. Effect of zinc oxide concentration on wettability time of untreated and hydrolyzed polyester fabric using conventional technique.

ZnO concentration gm/100ml	Untreated *	NaOH*	Untreated/ZnO	NaOH/ZnO
	fabrics			
	wettability/sec.			
1			0.62	0.12
2			0.61	0.3
4	4.7	0.08	0.94	0.48
6			0.82	0.43
8			0.81	0.43

Untreated=Untreated polyester fabric.
NaOH*= Hydrolyzed polyester using NaOH. Untreated/ZnO *= untreated polyester fabric treated using ZnO.
NaOH/ZnO*= Hydrolyzed polyester using NaOH then treated using ZnO.
Condition: temp. 20°C; NaOH conc.15%o.w.f.; wet pick up 90%; L: R 1:30 o.w.f..; time 24hr. Drip dry in ZnO; wet pick up 100%; curing 120°C; curing time 6 min.

microwave plays a role in the enhancement of the dyeing process [2, 28] . On the opposite way, the ZnO particles accumulate and increased by temperature so prevent the penetration or diffusion the dye particles leading to decrease the color strength.

Effect of Sodium Hydroxide and Zinc Oxide treatment on fastness properties (wash, light, perspiration) polyester fabric

Table (9) shows the result of the fastness properties of treated and untreated samples. The

TABLE 9. Effect of surface modification of polyester fabric on some of properties.

property / Techniques		Untreated fabric	polyester fabric finishing: Untreated/NaOH* m.w	Untreated/NaOH* Conv.	NaOH/ ZnO* m.w	NaOH/ ZnO* Conv.	Untreated/ZnO* m.w	Untreated/ZnO* Conv.
				Wettability / sec.				
Wettability		4.7	zero	0.08	2.1 min.	0.48 sec.	2.75 min.	0.94 sec.
				K/S				
Color strength		21.91	26.59	24.45	21.37	23.58	20.09	24.04
						Grade		
Wash fastness		4-5	4	4	4	4	4-5	4
Light fastness		6	5-6	5-6	6	6	5-6	5-6
Perspiration	Acid	4-5	4-5	4-5	4	4	4-5	4
	Alkali	4-5	4-5	4-5	4	4	4-5	4
				Reduction %				
Antibacterial %	*(E. coli)*	zero	72.56	71.44	63.64	64.77	57.23	64.27
	(S. aureus)	zero	80.2	80.12	70.73	72.85	59.15	69.69
				UPF Grade				
Ultraviolet protection factor		31.7	31.5	33.6	56.1	63.5	56.4	39.5
				Kg/5cm				
Tensile strength (Kg/5cm)	Warp	83.3	79	85	86.5	74.6	89.3	90
	Weft	67.6	67.5	71	53.5	63.6	70.3	76.3
				Percent %				
Elongation %	Warp	64.3	64.3	52.6	71	61.6	65	66.6
	Weft	43	42	43	39	42.6	43.3	43.3
				Gm.				
Tear strength (gm)	Warp	3300	1800	2433	5875	6425	6450	6600
	Weft	2550	2033	2550	5250	6583.3	5133.3	6450

* Untreated: polyester fabric

* Untreated/NaOH-m. w (temp. low; NaOH conc. 15% o.w.f.; wet pick up 90%; time 2.5 min.; L: R 1:30 o.w.f.)

* Untreated/NaOH-conv. (temp. 20°C; NaOH conc. 15% o.w.f.; wet pick up 90%; time 24 hr.; L: R 1:30 o.w.f.)

* NaOH/ZnO-m. w (temp. low; ZnO conc. 4% o.w.f.; time 5 min.; L: R 1:30 o.w.f; cured 200°C; time 3 min.)

* NaOH/ZnO-conv. (at room temp. low; ZnO conc. 4% o.w.f.; L: R 1:30 o.w.f; cured 120°C; time 6min.)

* Untreated/ZnO-m. w (temp. med.; ZnO conc. 5% o.w.f.; time 10 min.; L: R 1:30 o.w.f; cured 200°C; time 3 min.)

* Untreated/ZnO-conv. (at room temp.; ZnO conc. 6% o.w.f.; L: R 1:30 o.w.f; cured 120°C; time 6min.)

results ranged from good to very good for both wash and perspiration. This may be attributed to the physical bond that occurred between the fabric and penetrated dye as hydrogen bond, Van der Waals force. Slightly fading obtained because of uniformly on the surface [28].

Effect of Sodium Hydroxide and Zinc Oxide treatment on bacteria growth of polyester fabric

The reduction % of hydrolyzed polyester fabric with NaOH has increased because of OH- which causes damage of cell-wall of bacteria, i.e. disturbance of cell mechanism by cause of using ZnO which dissolute in acetic acid. The acid affects the membrane as it: a- a loss of membrane activity, b- increase the membrane fluidity, c-hyper- polymerization of cell-protein as well as, d- granules coagulation around the membrane. All of these leading to fission of membrane, so disorder in cell metabolism [27, 29-35]

Effect of Sodium Hydroxide and Zinc Oxide treatment on ultraviolet protection value of polyester fabric

High protection value depends on many

factors such are fabric type, porosity, density, moisture content. Polyester fabric has good–very good protection according to thickness and fabric constructur, after treated with UV absorber the protection value was increased [36-38]. In table (9) was observed that untreated polyester has very good protection this result may be due to woven fabrics showed better UV blocking and polyester has double bonds in polymer chain which can absorb and reflect a small amount of UV-R[36]. Otherwise, hydrolyzed polyester shows slightly increasing in UPF value this result may be due to alkali treatment led to surface roughness which can be affected on UPF value [26]. After treated (hydrolyzed polyester and untreated polyester fabric) with ZnO the protection value was increased which is reasonable as the fabric absorbed the ZnO particles [39] which made a coated layer on the surface fabric.

On the other hand, when comparing between microwave technique and the conventional method it was observed that conventional methods represent higher value than microwave technique this result may be due to microwave temperature increased particle size [40] which may cause large agglomeration on the surface which removed by washing [37].

Effect of the treatment of polyester fabric with Zinc Oxide on its Tenacity

Polyester fibers are strong because of it extremely crystalline; the tenacity being higher depends on the degree of crystalline. In the table(9) hydrolyzed polyester fabric showed decreasing in tensile and tear strength than the other treatment, this result may be due to hydrolysis reaction which obtains the structure of the polyester macromolecular and produces hydroxyl and carboxylate end group (hydrophilic, function group) causes losing of material weight, reduction fiber diameter; so decreasing in tenacity was occurred [41]. Comparing between untreated fabric and other treated fabrics an increasing in tensile and tear strength was observed may be due to zinc oxide particles coating layer on the surface of the fabric, i.e. hydrolysis decreased [42, 43]. On the other hand, when comparing tensile and tear results in warp and weft direction the warp shows higher results than weft because warp yarns are stressed more during weaving and the number of threads is higher than weft direction [43]. On the other hand, using the microwave technique shows decreasing in the tenacity of the fabric due to increasing the rate of hydrolysis [2].

TABLE 10. Durability of gained properties

Durability properties		**Washing cycle**								
	0			**5**			**30**			
				Fabrics						
		Untreated	ZnO a	NaOH/ZnO a	ZnO b	NaOH/ZnO b	ZnO a	NaOH/ZnO a	ZnO b	NaOH/ZnO b
				Bacteria Reduction%						
Antibacterial	*S. aureus*	zero	72.58	69.69	55.68	63.64	79.14	76.8	54.94	60.73
	E. coli	zero	64.27	64.77	47.67	66.28	70.14	55.56	44.4	51.82
						K/S				
Color strength		21.91	24.04	23.58	24.04	21.37	20.74	20.36	23.14	19.90
						UPF grade				
Ultraviolet protection factor		31.7	39.5	63.5	56.4	56.1	42.2	66.2	60.1	59.7

G*=Untreated fabric /ZnO a= untreated polyester fabric treated using ZnO via conventional technique

NaOH/ZnO a= Hydrolyzed polyester using NaOH then treated using ZnO via conventional technique ZnO b= untreated polyester fabric treated using ZnO via microwave technique

NaOH/ZnO b= Hydrolyzed polyester using NaOH then treated using ZnO via microwave technique

Effect of surface modification on the durability of gained properties of polyester fabrics

In the table (10) their slight enhancement in bacteria reduction in growth % and UPF grade this results may be due to that the ZnO in commercial form has large particle size which made large agglomerates so can be removed from the surface after washing make more levelness on the surface [37] but the results of K/S showed slightly fade.

Conclusions

In this work wettability performance of Polyester fabric depends on many parameters (time, concentration, wet pick up, liquor ratio, and temperature of the treatment). The enhancement in wettability was greater when used microwave technique. On the other hand, the particles of Zinc Oxide deposit on the surface of the polyester fabric have an effect on bacterial growth, UPF value, and dyeing process. Microwave irradiation energy is more efficient than the heating energy obtained by conventional techniques. To some extent, the use of microwave technology in the textile industry will minimize effort, time, energy, and production cost.

Acknowledgment

We thank Dr. Rania Shaker for her supports during measuring the antibacterial effect.

References

1. Bajaj P: Recent Advances in the Development of Silk-Like Polyester Fabrics. *Indian Journal of Fibre & Textile Research* 1996, **21**:79-89.

2. Haggag K, Zaher A, El-Sayed W: *Time/Energy Saving: Microwave Fixation of Ecofriendly Dye to Textile.* LAMBERT Academic Publishing: Verlag; 2013.

3. Nandy D, Thakker JH, Sengupta AK, Bhattacharya SD: Effect of hydrolytic action of NaOH in presence of methanol on aesthetic and comfort properties of polyester fabric. *NISCAIR-CSIR, India* 1999, **24**:279-283.

4. Tadesse M, Chavan R*: Catalyzation of Alkaline Hydrolysis of Polyester by Oxidizing Agents for Surface Modification,* vol. 22; 2015.

5. Büyükakıncı BY: Usage of Microwave Energy in Turkish Textile Production Sector. *Energy Procedia* 2012, **14**:424-431.

6. Grewal AS, Kumar K, Redhu S, Bhardwaj S: **Microwave assisted synthesi**s: a green chemistry approach. *Int Res J Pharm App Sci* 2013, **3**:278.

7. Elmaaty TMA, Mandour BA: ZnO and TiO2 nanoparticles as textile protecting agents against UV radiation: A review. *Asian Journal of Chemical Sciences* 2018:1-14.

8. Simonescu CM, Szekely AC, Perniu D, Capatina C: Characterization and Antimicrobial Activity of Chitosan/ZnO/Ag System. *REVISTA DE CHIMIE* 2014, **65**(8):871-875.

9. Espitia PJP, Soares NdFF, dos Reis Coimbra JS, de Andrade NJ, Cruz RS, Medeiros EAA: Zinc oxide nanoparticles: synthesis, antimicrobial activity and food packaging applications. *Food and bioprocess technology* 2012, **5**(5):1447-1464.

10. AATCC: Antibacterial Finishes on Textile Materials 100-2004. 2005.

11. AATCC: Absorbency of bleached textiles 79-2000. 2005.

12. ASTM: Breaking Strength/Elongation Strip Method 5035. 2016.

13. ASTM: Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus 1424. 1996.

14. Ibrahim NA, El-Gamal AR, Gouda M, Mahrous F: A new approach for natural dyeing and functional finishing of cotton cellulose. *Carbohydrate Polymers* 2010, **82**(4):1205-1211.

15. AATCC: Colorfastness to Light 16-2004. 2005.

16. AATCC: Colorfastness to Laundering, Home and Commercial: Accelerated 61-2003. 2005.

17. AATCC: Colorfastness to Perspiration 15-2002. 2005.

18. 18. AATCC: Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics 183-2004. 2005.

19. AATCC: Appearance of Fabrics after Repeated Home laundering 124-1996. 2000.

20. Haghighatkish M, Youscfi M: *Alkaline Hydrolysis of Polyester Fibers -Structural Effects,* vol. 1; 1992.

21. Bendak A, El-Marsafi S: Effects of chemical modifications on polyester fibres. *Journal of Islamic Academy of Sciences* 1991, **4**(4):275-284.

22. Cata A ŞM, Ionescu I, Tanasie C, Miclau M: Alkaline hydrolysis of polyethylene terephthalate

under microwave irradiation. *Rev Roum Chim* 2017, **62**:531-538.

23. Van der Walt G, Van Rensburg N: *A review of low add-on and foam application techniques;* 1984.
24. Patil SD, Raichurkar P: Study the effect of material to liquor ratio in yarn dyeing. *Centre for textile functions (CTF), NMIMS University, Joint collobarative projects by CTF and PSSGL ALOK, Welspun* 2013.
25. 25. Rimbu C, Vrinceanu N, Broasca G, Farima D, Ciocoiu M, Campagne C, Suchea MP, Nistor A: Zinc oxide application in the textile industry: surface tailoring and water barrier attributes as parameters with direct implication in comfort performance. *Textile Research Journal* 2013, **83**(20):2142-2151.
26. Nourbakhsh S, Montazer M, Khandaghabadi Z: Zinc oxide nano particles coating on polyester fabric functionalized through alkali treatment. *Journal of Industrial Textiles* 2018, **47**(6):1006-1023.
27. Fiedot-Toboła M, Ciesielska M, Maliszewska I, Rac-Rumijowska O, Suchorska-Woźniak P, Teterycz H, Bryjak M: Deposition of zinc oxide on different polymer textiles and their antibacterial properties. *Materials* 2018, **11**(5):1-16.
28. Kim SS, Leem SG, Ghim HD, Kim JH, Lyoo WS: Microwave heat dyeing of polyester fabric. *Fibers and Polymers* 2003, **4**(4):204-209.
29. Anand SC, Kennedy JF, Miraftab M, Rajendran S: *Medical and healthcare textiles:* Elsevier; 2010.
30. Badea GI, Radu GL: Introductory Chapter: Carboxylic Acids-Key Role in Life Sciences. *Carboxylic Acid: Key Role in Life Sciences* 2018:1.
31. Healthcare G: Use of sodium hydroxide for cleaning and sanitizing chromatography media and systems. In.: Application note 18-1124-57 AE; 2006.
32. Lu C-H, Yeh C-H: Influence of hydrothermal conditions on the morphology and particle size of zinc oxide powder. *Ceramics International* 2000, **26**(4):351-357.
33. 33. Myers RP: The effect of hydroxyl ion concentration on the thermal death rate of Bacterium coli. *Journal of bacteriology* 1928, **15**(5):341.
34. Wu Y, Bai J, Zhong K, Huang Y, Qi H, Jiang Y, Gao H: Antibacterial activity and membrane-disruptive mechanism of 3-p-trans-coumaroyl-2-hydroxyquinic acid, a novel phenolic compound from pine needles of *Cedrus deodara***,** against *Staphylococcus aureus. Molecules* 2016, **21**(8):1084.
35. Yamamoto O: Influence of particle size on the antibacterial activity of zinc oxide. *International Journal of Inorganic Materials* 2001, **3**(7):643-646.
36. Demirović O, Tarbuk A, Grancarić AM: EDA Modified Polyester Fabric for Better UV Protection. In: *International Research/Expert Conference" Trends in the Development of Machinery and Associated Technology", Turkey: 2018*: Citeseer; 2018: 289-292.
37. Kathirvelu S, D'souza L, Dhurai B: *UV protection finishing of textiles using ZnO nanoparticles.* 2009.
38. Saravanan D: UV protection textile materials. *AUTEX Research Journal* 2007, **7**(1):53-62.
39. Ghani ARRA, Qorshi WAR, Romyia AFAHA, El-Sayd ERS: Treatment of Children's Garments Natural Fabrics for Protection Against Ultraviolet Radiation. *Health phys* 2015, **67**:131-139.
40. Belay A, Bekele B, REDDY AC: Effects of Temperature and Polyvinyl Alcohol Concentrations in the Synthesis of Zinc Oxide Nanoparticles. *Digest Journal of Nanomaterials & Biostructures (DJNB)* 2019, **14**(1).
41. Bide M, Phaneuf M, Brown P, McGonigle G, LoGerfo F: Modification of polyester for medical uses. In: *Modified fibers with medical and specialty applications.* edn.: Springer; 2006: 91-124.
42. Emam A: Treating Natural Leather and woven fabrics with Nano zinc oxide on the properties of clothing comfort. *International Journal of Scientific Research Engineering & Technology* 2017, **6**:445-466.
43. Kampeerapappun P: Effect of zinc oxide loaded polyester fibers on the color, mechanical properties and antibacterial action of woven fabric. *Journal of Metals, Materials and Minerals* 2019, **28**(2):33-40.

إجراء تغييرات بسطح أقمشة عديد الاستر بإستخدام أشعة الميكروويف بهدف تقليل التلوث بالصناعات النسجية عن طريق التحكم في الطاقة المستخدمة و كذا زمن المعالجة

رحاب سمير رزق ، وفاء أنور السيد، نجاح سيد عاشور، أمنية خيري أحمد
جامعه عين شمس – كليه البنات – قسم الاقتصاد المنزلى- القاهره- مصر

في هذا العمل تم معالجة ألياف البولي استربهيدروكسيد الصوديوم بإستخدام تقنية الميكروويف بجانب طريقة الاستنفاذ كطريقة عادية بغرض تحسين خاصية البلل، تحت دراسة العوامل التي أثرت على هذه الخاصية مثل تأثير تركيز هيدروكسيد الصوديوم و كذلك درجة الحرارة و زمن المعالجة و نسبة الحمام و كذلك درجة تشبع القماش بمحلول المعالجة. كي تتم معالجة القماش المعالج و الغير معالج بأكسيد الزنك نعرض دراسة تأثيره على خاصية البلل و بعض الخواص الأخرى مثل المقاومة للميكروبات و امتصاص الصبغات و القدرة على مقاومة الاشعة فوق البنفسجية بإستخدام التقنيتين. أظهرت النتائج إيجابية تحسين خاصية البلل عند استخدام هيدروكسيد الصوديوم كما أظهرت المعالجة بهيدروكسيد الصوديوم و أكسيد الزنك تحسين خواص أقمشة البولي استر و إيجابياتها في مقاومة البكتريا و الاشعه فوق البنفسجية و كذلك قدرتها على امتصاص الصبغات، و أثبتت تقنية الميكروويف تفوقها على الطرق التقليدية للمعالجات.