Egypt. J. Chem. **Vol. 65,** No. 6 pp. 37- 45 (2022)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Nano ZnO Provides Multifunctional on Dyed Polyester Fabrics with Enaminone-Based Disperse Dyes

Morsy A. El-Apasery[1*], Fathy A. Yassin[2], Mahmoud E. A. Abdellatif [2]

[1] *Dyeing, Printing and Auxiliaries Department, Textile Research and Technology Institute, National Research Centre, Cairo 12622, Egypt*.

[2] *Department of Chemistry, Faculty of Science, Zagazig University, Egypt*.

Abstract

To provide these fabrics practical qualities, we treated the colored polyester texture with dispersion dyes that we had previously produced. After treating the fabric with zinc oxide ZnO nano particle size NPs, the self-cleaning and light fastness were investigated and it was discovered that these properties were greatly enhanced. The polyester texture's capacity to shield against UV light has been tested.

Keywords: *Disperse dyes, dyebath reuse. Ultraviolet protection factor*.

1. Introduction

Because UV radiations have negative and dangerous effects on human health, prolonged exposure to them can lead to skin cancer. Textiles were utilized in the past, and some changes to the thickness of these textiles were made to assist guard against UV damage, such as umbrellas and caps, but these changes were insufficient to improve the effectiveness of textiles against UV radiation.

As a result, some prospective treatments for improving the performance of textiles in guarding against UV radiation, particularly on human skin, have been investigated [1-18]. The term ultraviolet protection factor (UPF) was coined to describe the tissue's ability to defend itself from UV light damage [8, 9, 19]. *Polyester textures provide UV protection,* can be treated for specific natural and inorganic synthetic materials, and are referred to as blockers. Semiconductor oxides like as TiO_2 and ZnO are examples of inorganic blockers. ZnO has recently been credited as a reasonable and safe blocker for bright beams, since it holds beams well and over a wide range, hence it is recommended to use it as a UV blocker.

In our previous research [10-13], a number of new disperse dyes were prepared that were used to dye polyester fabrics. Here in this study, polyester fabrics were treated with nano-particles of zinc oxide in order to give these fabrics some properties such as improving the light fastness and self cleaning property.

*Corresponding author e-mail: elapaserym@yahoo.com.; (**Morsy Ahmed Elapasery**).
Receive Date: 01 January 2022, Revise Date: 05 January 2022, Accept Date: 11 January 2022
DOI: 10.21608/EJCHEM.2022.114178.5192

2. Materials and Methods

General method for the Synthesis of Disperse Dyes **1-6** which applied in this survey had been annotated in our published study [10,12].

Dyeing procedure

A- First dyeing

El-Mahalla El-Kobra Company, Egypt, provided scoured and bleached 100% polyester fabric. The disperse dyes **1-6**, a dispersion of the dyes were produced by dissolution of the appropriate amount of dyes (3% shades) in 2 ml DMF and then added drop wise with stirring to the dye bath (liquor ration 1:30) containing dispersing agent. The pH of the dye bath was adjusted to 5.5, and the wetted-out polyester fabrics were added. We performed dyeing by raising the dye bath temperature to 130°C at and holding it at this temperature for 60 min. After they were cooled to 50°C, the dyed fibres' were rinsed with cold water and reduction-cleared (1 g/L sodium hydroxide, 1 g/L sodium hydrosulfite, 10 min, 80°C). The samples were rinsed with hot and cold water and, finally, air dried [12].

B- Dyeingbaths reuse

After dyeing, the dyebath was analyzed and reconstituted with the necessary amount of fresh water to maintain a constant liquor ratio of the original volume. Residual dyebath pH was measured in order to keep pH at 5.5. Dyebath reuse in dyeing was being carried out by the same procedures of the previously two techniques. Finally a reduction-cleared using sodium hydroxide (3 g/L) and sodium hydrosulphite (2 g/L) and soaped with 2% nonionic detergent (pH 8) at 50 °C for 15 minutes to improve washing fastness [12].

Photo-Stimulated Color Removal on Polyester

A total of 0.01 g/L of methylene blue was marked on both the treated ZnO NPs (1–3%) treated polyester and the untreated fabrics. The polyester fabrics were illuminated through exposure to an ultraviolet lamp for 12 hours [19].

Ultraviolet Protection Factor Measurement

It is worth noting that the ultraviolet protection factor is the capability of dyed polyester fabric to block ultraviolet, which was conducted in an ultraviolet visible spectrophotometer 3101[19].

Treatment for Dyeing baths

Dyeing baths that had been adjusted to pH4.5 after the first reuse had been used as a new dye bath in the same conditions as the first dyeing and the same for the third and fourth dyeing.

Light fastness

The light fastness test was performed using a carbon arc lamp and continuous illumination for 35 hours in line with ISO 105-B02:1988 test method 9. The influence on the colour of the examined samples was measured using the blue scale

Treatment of fabrics

Pre-treatment

Fabric samples were soaked in a 10 g/l nonionic detergent solution (Hostapal, Clariant) for 10 minutes before being dispersed with ZnO NPs (0-2.5 percent w/w) for 15 minutes with gentle stirring. The materials were squeezed to eliminate excess dispersion before being dried in a 70°C oven for 10 minutes. The fabrics were queried for 3 minutes at 140 degrees Celsius. The fabrics were washed at 60 oC for 15 minutes in an aqueous solution with a liquor ratio of 1:50 containing 3 g/l nonionic detergent solution (Hostapal, Clariant) [17].

Post-treatment

After dyeing, the fabric samples were soaked in a 10 g/l nonionic detergent solution (Hostapal, Clariant) for 10 minutes before being dispersed with ZnO nano particles (0-2.5 percent w/w) under gentle stirring for 15 minutes. The materials were squeezed to eliminate excess dispersion before being dried in a 70°C oven for 10 minutes. The fabrics were queried for 3 minutes at 140 degrees Celsius. The fabrics were washed at 60 ºC for 15 minutes in an aqueous solution with a liquor ratio of 1:50 containing 3 g/l nonionic detergent solution (Hostapal, Clariant) [17].

3. Results and Discussion

Scheme 1 depicts the chemical structure of the disperse dyes used to colour the polyester fabrics in this manner. [10-13].

3.1. Ultraviolet protection factor UPF.

In general, it is clear from Table 1. that treating polyester fabrics before the dyeing process (pre-treatment) with nano-zinc oxide particles was better than treating polyester fabrics after the dyeing process (post-treatment), for all dyes **1-6** except for dyes **4** and **6**, which was the opposite, and the UPF values of untreated fabrics were always lower than UPF values for treated dyed fabric for all prepared dyes **1-6**. In detail with regard to the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 1 g/L, we find that the dyes numbers **1** and **3** were better than treating polyester fabrics after the dyeing process with UPF values before performing the dyeing process with nano-particles of zinc oxide at the rate of 1%. As for dyes numbers **4**, **5** and **6**, the exact opposite is what happened. Regarding the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 2 g/L, we find that the dyes **2**, **3** and **5** were better than treating polyester fabrics with nano-particles of zinc oxide, with UPF values before the dyeing process.

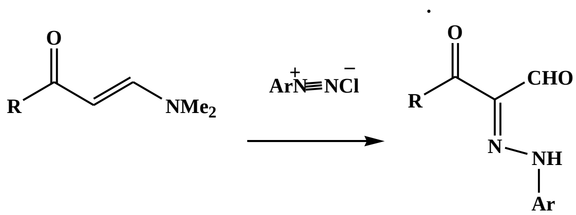
For the dyes **1**, **4** and **6**, the exact opposite is what happened. Regarding the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 3 g/L, we find that the dyes **1**, **2** and **5** were better than treating polyester fabrics with nano-particles of zinc oxide with UPF values before performing the dyeing process. As for the dyes **3**, **4** and **6**, the opposite is what happened. When evaluating the best percentage of ZnO NPs that gave the best UPF values for the prepared dyes. We find that 1 g/L of ZnO NPs is the best for all dyes, except for dyes **5** and **6**, where 2 g/L of ZnO NPs is the best.

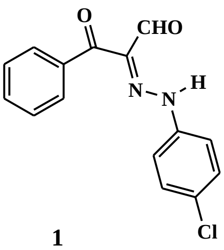
3.2. Dyeing baths treatment

Table 2 shows that the dye baths left over from the previous dying operation can be reused. We employed dyeing baths after the first dyeing procedure in a prior study [12], and the results were satisfactory, but we discovered that the same dyeing baths may be used for dyeing again. The first purpose is to treat wastewater before it is disposed of, which is good for the environment, and the second goal is to obtain dyed materials at no extra expense. As indicated from the colour strength K/S of dyed samples, Table 2 illustrates that recycling dye baths can remove a significant quantity of dye (up to 95 percent) from the dying baths.

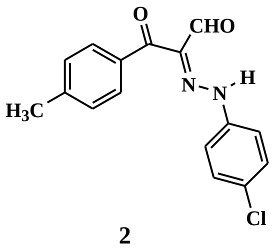
3.3. Light fastness enhancement

It is clear from the table 3, the dyeing treatment before the dyeing process (pre-treatment) with nano-oxide particles was better than the treatment for polyester fabrics after the dyeing process (post-treatment) for all dyes **1-6**. And in detail with regard to treating polyester fabrics with nano-particles of zinc oxide at a rate of 1 g/L, we find that dyes**1** and **6**

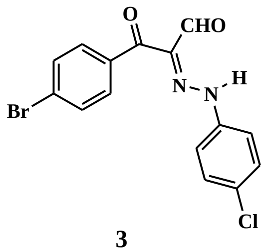




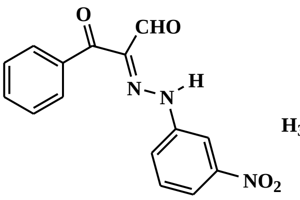
1



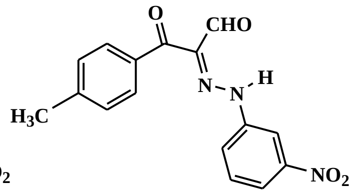
2



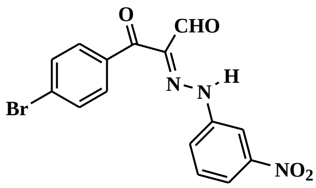
3



4



5



6

Scheme 1. Chemical structures of the disperse dyes 1-6

Table 1. UPF of treated polyester fabrics

Dye No	Treatment	ZnO %	AATCC Test Method 183 - UPF	AATCC - UVA Trans.	AATCC - UVB Trans	AATCC test method183 - UVA	AATCC test method183 - UVB
1	Untreated		738.4	0.1	0.2	99.9	99.8
	Pre-treated	1	817.4	0.1	0.1	99.9	99.9
		2	476.5	0.1	0.2	99.9	99.8
		3	369.8	0.2	0.3	99.8	99.7
	Post-treated	1	452.2	0.2	0.2	99.8	99.8
		2	707.9	0.1	0.2	99.9	99.8
		3	372.5	0.2	0.3	99.8	99.7
2	Untreated		396.0	0.2	0.3	99.8	99.7
	Pre-treated	1					
		2	394.6	0.2	0.3	99.8	99.7
		3	368.7	0.2	0.3	99.8	99.7
	Post-treated	1	414.1	0.2	0.3	99.8	99.7
		2	379.2	0.2	0.3	99.8	99.7
		3	326.5	0.3	0.3	99.7	99.7
3	Untreated		308.7	0.2	0.4	99.8	99.6
	Pre-treated	1	402.8	0.2	0.3	99.8	99.7
		2	335.6	0.2	0.3	99.8	99.7
		3	278.1	0.3	0.4	99.7	99.6
	Post-treated	1	313.8	0.3	0.3	99.7	99.7
		2	258.9	0.4	0.4	99.6	99.6
		3	295.5	0.3	0.3	99.7	99.7

Continue : **Table 1.** UPF of treated polyester fabrics

Dye No	**Treatment**	**ZnO %**	**AATCC Test Method 183 - UPF**	**AATCC - UVA Trans.**	**AATCC - UVB Trans**	**AATCC test method183 - UVA**	**AATCC test method183 - UVB**
4	Untreated		277.8	02	0.4	99.6	99.8
	Pre-treated	1	435.7	0.2	0.2	99.8	99.8
		2	186.5	0.4	0.6	99.6	99.4
		3	164.7	0.5	0.6	99.5	99.4
	Post-treated	1	602.7	0.1	0.2	99.9	99.8
		2	564.1	0.2	0.2	99.8	99.8
		3	271.8	0.3	0.4	99.7	99.6
5	Untreated		380.4	0.2	0.3	99.8	99.7
	Pre-treated	1	413.4	0.2	0.2	99.8	99.8
		2	692.5	0.1	0.1	99.9	99.9
		3	523.0	0.1	0.2	99.9	99.8
	Post-treated	1	472.7	0.1	0.2	99.9	99.8
		2	341.0	0.2	0.3	99.8	99.7
		3	425.4	0.2	0.2	99.8	99.8
6	Untreated		220.1	0.5	0.4	99.5	99.6
	Pre-treated	1	252.7	0.3	0.4	99.7	99.6
		2	344.0	0.2	0.3	99.8	99.7
		3	277.8	0.3	0.4	99.7	99.6
	Post-treated	1	337.9	0.3	0.3	99.7	99.7
		2	509.1	0.2	0.2	99.8	99.8
		3	284.8	0.3	0.3	99.7	99.7

Table 2. Reusing of dyeingbaths

Dye No	**K/S**				**Difference %**
	First dyeing	**First Dyeing baths reuse**	**Second Dyeing baths reuse**	**Third Dyeing baths reuse**	
1	12.20	0.17	0.14	0.12	99.02
2	10.21	0.18	0.13	0.14	98.63
3	11.30	0.17	0.11	0.11	99.03
4	4.46	0.25	0.13	0.14	96.86
5	3.35	0.14	0.11	0.12	96.42
6	3.94	0.17	0.14	0.11	97.21

Table 3. Light fastness of treated polyester fabrics.

Dye No	Treatment	ZnO %	Light Fastness	Dye No	Treatment	ZnO %	Light Fastness
	Untreated		3-4		Untreated		3
		1	3-4			1	3
	Pre-treated	2	4		Pre-treated	2	4
1		3	3	4		3	4
		1	3			1	3
	Post-treated	2	3		Post-treated	2	3
		3	3			3	3
	Untreated		5		Untreated		3
		1	-			1	3
	Pre-treated	2	3-4		Pre-treated	2	2-3
2		3	5	**5**		3	4
		1	3			1	3
	Post-treated	2	3		Post-treated	2	3
		3	3			3	3
	Untreated		3		Untreated		2-3
		1	3			1	3
	Pre-treated	2	4		Pre-treated	2	2-3
3		3	2	**6**		3	4
		1	3			1	2-3
	Post-treated	2	3		Post-treated	2	2-3
		3	3			3	2-3

Table 4. Dye removal of polyester fabrics

Dye No	Treatment	ZnO %	Dye Removal	Dye No	Treatment	ZnO %	Dye Removal
	Untreated		50		Untreated		50
		1	60			1	40
	Pre-treated	2	50		Pre-treated	2	60
1		3	50	4		3	50
		1	70			1	60
	Post-treated	2	40		Post-treated	2	60
		3	50			3	60
	Untreated		50		Untreated		50
		1	-			1	60
	Pre-treated	2	50		Pre-treated	2	60
2		3	50	**5**		3	50
		1	50			1	50
	Post-treated	2	60		Post-treated	2	60
		3	50			3	70
	Untreated		50		Untreated		50
		1	50			1	40
	Pre-treated	2	40		Pre-treated	2	50
3		3	50	**6**		3	50
		1	50			1	60
	Post-treated	2	50		Post-treated	2	50
		3	60			3	50

had the values of light fastness in treating polyester fabrics before the dyeing process with nano-particles of zinc oxide was ((3-4) and (3)). It is better than treating polyester fabrics after the dyeing process, as it was ((3) , (2-3)), respectively.

For dyes **3**, **4**, and **5**, the value of light fastness was equal as it was ((3, (3), (3)) for both methods, respectively. Regarding the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 2 g/L, we find that the dyes **1**, **2**, **3** and **4** had the values of light fastness in treating polyester fabrics before the dyeing process with nano-particles of zinc oxide was ((4), (3-4), (4), (4)), it is better than treating polyester fabrics after the dyeing process, where it was ((3), (3), (3), (3)), respectively.

For dye **5**, the opposite happened where the value of light fastness was (3) versus (2-3). For Dye **6**, the light fastness value was equal, it was (2-3) for both methods, respectively. We find that the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 3 g/L, the dyes **4**, **5** and **6** had the values of light fastness by treating polyester fabrics before the dyeing process with nano-particles of zinc oxide was ((4), (4), (4)), it is better than treating polyester fabrics after the dyeing process, as it was ((3), (3) ,(2-3)), respectively.

On the other hand for dye **3**, the opposite happened where the value of light fastness (3) vs. (2). For dyes **1** and **2**, the value of light fastness was equal as ((3, (3)) for both methods, respectively. When evaluating the best percentage of ZnO NPs that gave the best light fastness values for the prepared dyes. We find that 2 g/L of ZnO NPs is the best for all dyes, except for dyes umbers **5** and **6**, whereby 3 g/L of ZnO NPs is the best.

3.4. Self cleaning

In general, it is clear from Table 4, regarding the removal of colors that treating polyester fabrics after the dyeing process (post-treatment) with nano-particles of zinc oxide was better than treating polyester fabrics before the dyeing process (pre-treatment), for all dyes **1-6**, and the values of dye removal for untreated dyed fabrics were always lower than values of dye removal for treated dyed fabrics for all prepared dyes **1-6**.

In detail, regarding the treatment of polyester fabrics with nano-particles of zinc oxide at a rate of 1 g/L, we find that the dye removal values of dyes **1**, **3** and **6** in the treatment of polyester fabrics after the dyeing process with nano-zinc oxide particles are 70, 60 and 60% and is better than treating polyester fabrics before the dyeing process, they were 60, 40 and 40%, respectively. For dye **5**, the opposite happened, where the value of dye removal was 60% compared to 50%.

For dye **3**, the value of dye removal was equal, as it was 50% for both methods. As for the treatment of polyester fabrics with nano-zinc oxide particles at a rate of 2 g/L, we find that the dyes **2** and **3** were the values of dye removal when treating polyester fabrics after the dyeing process with nano-zinc oxide particles is 60 and 50% and is better than treating polyester fabrics before the dyeing process, they were 50 and 40%, respectively. For dye **1**, the opposite happened, where the value of dye removal was 50% versus 40%.

For the dyes **4**, **5**, and **6**, the value of dye removal was equal, as it was 60, 60 and 50% for both methods, respectively. As for the treatment of polyester fabrics with nano-zinc oxide particles at a rate of 3 g/L, we find that the dye removal values of dyes 3, **4** and **5** were 60, 60, and 70% for polyester fabrics treatment after the dyeing process with nano-zinc oxide particles and better than treating polyester fabrics before dyeing process that was 50, 50 and 50%, respectively.

For dyes **1**, **2**, and **6**, the value of dye removal was equal, as it was 50, 50 and 50% for both methods, respectively. When evaluating the best percentage of ZnO NPs that gave the best values for dye removal for the prepared dyes. We find that 1 g/L of ZnO NPs is the best for all dyes, except for dyes **3** and **5**, where 3 g/L of ZnO NPs is the best.

4. Conclusions

In conclusion, these prepared disperse dyes added value because the polyester fabric dyed with these dyes gave good results against ultraviolet rays that harm the skin, and the ZnO NPs treatment is a simple method that is promising for producing substrates with good self-cleaning and light fastness properties.

5. Conflicts of interest

There are no conflicts to declare.

6. References

1 Elapasery, M.A.; Hussein, A., Eladasy, A., Saleh, M., Kamel, M. Microwave Assisted Synthesis of Some Azo Disperse Dyes with Antibacterial Activities. Part 1, *Egyptian Journal of Chemistry*, 2019, 62(5), 853-859.

2 Saleh, M. O. ; El-Apasery, M. A. ; Hussein, A. M. ; El-Adasy, A.A. ; Kamel, M. M. Microwave assisted synthesis of some azo disperse dyes part 2: Eco-friendly dyeing of polyester fabrics by using microwave irradiation. European Journal of Chemistry, 2021,12, 64-68

3 El-Apasery, M.A.; Hussein,A. M.; Saleh, M. O, and El-Adasy, A.A. M.; Microwave Assisted Synthesis of Some Azo Disperse Dyes part 3: Dye bath Reuse in Dyeing of Polyester, Egypt.J.Chem, 2021, 64(8), 4663-4667.

4 El-Tahlawy, K.; El-Nagar, K.; Elhendawy, A. G. Cyclodextrin-4 Hydroxy benzophenone inclusion complex for UV protective cotton fabric.*The Journal of the Textile Institute, 2007*, 98, 453-462.

5 El-Apasery, M. A. ; Hussein, A., Saleh, M., Eladasy, A., Nour El-Din, N. Microwave-assisted dyeing of wool fabrics with natural dyes as eco- friendly dyeing method: part II. The effect of using different mordants', *Egyptian Journal of Chemistry*, 2021. 64(7), 3761-3766.

6 Dulęba-Majek, M. Transmission of UV radiation through woven fabrics in dependence on the liter-thread spaces. *Fibers & Textiles in Eastern Europe*, 2009, 17, 34-38.

7 El-Apasery, M. A. ; Hussein, A., Saleh, M., Eladasy, A., Nour El-Din, N. Microwave-assisted dyeing of wool fabrics with natural dyes as eco- friendly dyeing method: part I. Dyeing performance and fastness properties', *Egyptian Journal of Chemistry*, 2021, 64(7), 3751-3759.

8 Al-Etaibi, A.M.; El-Apasery, M.A. Dyeing of polyester with disperse dyes: Part 3. Characterization of ZnO nanoparticles treated polyester fabrics for antibacterial, self-cleaning and UV protective. *Int. J. ChemTechRes.* 2016, *9*, 162–169.

9 Elapasery, M.A.; Abdelghaffar, R., Kamel, M., Kamel, M., Youssef, B., Haggag, K. 'Microwave, Ultrasound Assisted Dyeing- Part I: Dyeing characteristics of C.I. Disperse Red 60

on polyester fabric', *Egyptian Journal of Chemistry*, 2017, 143-151.

10 El-Apasery, M. A. ; Yassin, F., Abd El-Azim, M., Abdellatif, M., Mashaly, H. Enaminones-Assisted Synthesis of Disperse Dyes. Part 2: High Temperature Dyeing of Polyester Fabrics', *Egyptian Journal of Chemistry*, 2020, 63(9), 3209-3216.

11 Elapasery, M. A.; Yassin, F. A.; Abdellatif, M. E. A. Comparison between Low and High Temperature Dyeing of Polyester Fabrics Dyed with Disperse Dyes derived from Enaminon. *Egypt. J. Chem.* 2021, 64(7), 6591-6599.

12 El-Apasery, M. A. ; Yassin, F., Abdellatif, M. Enaminones-Assisted Synthesis of Disperse Dyes. Part 3: Dyebath Reuse and Biological Activities', *Egyptian Journal of Chemistry*, 2020, 63(9), 3503-23158.

13 El-Apasery, M. A. ; Yassin, F., Abd El-Azim, M., Abdellatif, M. Enaminones-Assisted Synthesis of Disperse Dyes. Part 1: Low Temperature Dyeing of Polyester Fabrics', *Egyptian Journal of Chemistry*, 2020, 63(3), 1101-1108.

14 El-Apasery, M. A. ; Shakra, S.; Abbas, D.; Gaffer, H.; Allam, A. Synthesis of some azo disperse dyes based on pyridone moiety and their application on polyester fabrics.*Egypt. J. Chem.*2018, *60*, 97–102.

15 Zohdy, M.; Hossamy, M.; Wahab, A.; Naggar, E.; Fathalla, A.; Ali N. Novel UV-protective formulations for cotton, PET fabrics and their blend utilizing irradiation technique. *European Polymer Journal*, 2009, 45, 2926-2934.

16 Grifoni, D.; Bacci, L.; Lonardo, S.; Pinelli, P.; Scardigli, A.; Camilli, F.; Sabatini, F.; Zipoli, G.; Romani A. UV protective properties of cotton and flex fabrics dyed with multifunctional plant extracts. *Dyes and pigments*, 2014, 105, 89-96.

17 El-Apasery, M.A.; Saleh, M.O. Monoazo disperse dyes based on pyrazolopyrimidinones provide added value. *Egypt. J. Chem.* 2021, *64*, 4669–4674.

18 Mashaly, H. M.; Abdelghaffar, R. A.; Kamel, M. M.; Youssef, B. M. Dyeing of polyester fabric using nano disperse dyes and improving their light fastness using ZnOnano powder. *Ind. J. Sci. Tech.*2012, *7*, 960–967.

19 Al-Etaibi, A. M.; El-Apasery, M. A. Nano TiO_2 Imparting Multifunctional Performance on Dyed Polyester Fabrics with some Disperse Dyes Using High Temperature Dyeing as an Environmentally Benign Method, *Int. J. Environ. Res. Public Health* 2020, 17, 1377.