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Antibacterial, Self-Cleaning, UV Protection and Water Repellent Finishing of Polyester Fabric for Children Wheelchair

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Abstract

THE present work represents wheelchair furnishing in order to develop the usual leather furnishing, as it can be printed and prepared to serve the Disabled children since it conserves water, and reduces in the long run energy, washing cost, and time too, and it also increases moisture resistance, in addition to Aesthetics. A pure polyester fabric was treated with Zinc Oxide nanoparticles as well as a mixture of silicone rubber and hexane, to obtain the desired self-cleaning, anti-bacterial and UV protection finishings, as well as the fabric's water resistance. The finished samples were tested and the experimental results indicate that all the required measurements are included and discussed in detail.
Keywords: Zinc oxide. Nano particles; UV; Silicone Rubber. Hexane

Introduction

Polyester has a wide range of applications, particularly in the textile industry, where it is valued for its superior strength, chemical resistance, processability, rapid drying, and dimensional stability. [1, 2]

Additionally, microorganisms can grow in fabrics as a result of the extensive adsorption of metabolic byproducts from skin sweat and sebaceous glands, which can cause unpleasant odour, stains, and discoloration as well as compromise the mechanical properties of textiles and result in cross-contamination.

Additionally, house dust mites can produce an allergic reaction in 50% of asthma sufferers, and this allergy is a major contributor to a serious global health issue.

Therefore, there is an urgent demand for anti-mite materials to combat the illness and safeguard public health. The mechanics underlying anti-mite textiles are still unclear, and they are seldom ever explored. As a result, the creation of antimicrobial, anti-mite, and self-cleaning fabric finishing techniques is greatly sought and a key focus of this effort. [3]

Zinc oxide nanoparticles are special in that they have photocatalytic, electrical, optical, dermatological, and antibacterial capabilities. Because of this, it is possible to create textiles that are both self-cleaning and antibacterial.[4]

In this regard, the creation of novel antibacterial nanomaterials and nanoparticles (NPs) appears to be quite beneficial. Due to their antibacterial, antiviral, and antifungal capabilities, metal-based NPs and metal oxide NPs have previously been used as additives in a variety of goods, including medicinal items. [5-11]

Zinc oxide (ZnO) NPs, in particular, have been shown to be extremely efficient against many types of bacteria and viruses, making them one of the most suitable nanomaterials for coating textiles.[12]

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The ZnO-treated cloth may be UV-protective and self-cleaning by preventing the development of microorganisms. Because zinc oxide is non-toxic and chemically stable when exposed to high temperatures and UV radiation, its ability to block UV rays is significantly increased. ZnO has a near-UV wavelength and is transparent to visible light. [13-19] In addition to a number of chemical and physical features, nanoprocessing provides it certain unique properties in terms of light, electricity, magnetism, and heat that are not present in regular ZnO products. [4, 13, 15, 19-22]

In the present work, polyester fabric is treated with zinc oxide nanoparticles (ZnO NPs) to obtain antibacterial, self cleaning and UV protection finishing. Silicone Rubber with Hexane are also used to develop water repellence finishing to polyester fabric in other treatment.

Transfer printing is also applied on the finished polyester fabric, so that it guarantees exact, unlimited color match, recreate graphic details and complex patterns with great accuracy on fabric.

2. Materials and methods

2.1. Materials

(100%) Polyester fabric is kindly obtained from El-Mahala Company for Spinning and Weaving, El-Mahala (Egypt).

Sigma-Aldrich provides zinc oxide (nanopowder, 50 nm particle size; >97%). (Egypt).

By ICI Company, UK, a dispersing agent (Matexil DA-N) was provided.

INFRA Color Dyeing Machine (R.B.electronic & enginiring PVT. Ltd.), Mumbai-India.

RTV silicone is purchased from ADMICO Company (Egypt).

Hexane is purchased from El Gomhoureya Pharmaceutical Company (Egypt).

Water contact angles were reported on OCA 15EC DATAPHYSICS, Germany

All chemicals are of laboratory grade and are all purchased from El Gomhoureya Pharmaceutical Company.

2.2. Methods

2.2.1. Preparation of ZnO NPs

A method that has been previously described in the literature was used to create zinc oxide nanoparticles. To achieve a nucleation rate greater than the growth rate, the preparation procedure was carried out at a high level of super-saturation. Using an oil bath, 5.5 g of zinc (II) chloride was dissolved in 200 mL of distilled water at 90 °C. The sodium hydroxide aqueous solution (16 mL of 5 M NaOH) was carefully added over 10 min at 90 C while the zinc chloride aqueous solution was gently stirred. By precipitation, the generated particles were separated from the supernatant solution. To lessen the overall concentration of sodium chloride as a byproduct, the precipitate was washed with distilled water. An aqueous solution of silver nitrate served as confirmation that all of the sodium chloride had been removed. After being collected using sec-propanol, the particles were exposed to ultrasonic waves for 10 minutes at room temperature in order to break up the micro agglomerates and release the ZnO nanoparticles. The generated nanoparticles underwent thermal treatment at 250° C for 5 hours after centrifugation at 6000 rpm for 20 min.

2.2.2. Coating ZnO NPs onto textiles samples

Bleached polyester fabrics were washed in running water to reach the equivalent absorption and avoid the unlevelling.

The samples were cut 5cm x 5cm each with a weight of 1gm for antibacterial, self-cleaning and water repellent finishing.

The experiment is run by ZnO NPs with concentrations (0, 0.05, 0.1, 0.15) gm/l, and the dispersing agent is used by concentrations (0, 0.05, 0.1, 0.15) mg/l.

The finishing procedures were carried out in the Infracolour device at temp.120° C for 60 min.

The substrates were cooled gradually by decreasing its temperature 5 degrees/min. until the temperature reaches 60° C.

The samples left to dry at room temperature , then they washed well by tap water.

2.2.3. Coating Silicone Rubber + Hexane onto textile samples

At room temperature vulcanized (RTV), put 5 gm of silicone rubber and 50 ml of Hexane solution. The finishing procedures are carried out with the sample from 3-5 min. [11, 23-25]

2.3. Measurements

2.3.1. Measurements of ZnO NPs padding

L.R	1:50
W.O.S	1 gm
ZnO	Where x= (0, 0.05, 0.1, 0.15)g/l
Dispersing agent	Where x= (0, 0.05, 0.1, 0.15)g/l
Time	60 min.
Temperature	120° C

2.3.2. Measurements of Antimicrobial finishing

The disc agar diffusion technique was used to examine the antibacterial activity of ZnO NPS. The four representative test organisms were Aspergillus niger NRRL-A326 (fungus), Staphylococcus aureus ATCC 6538-P (G+ve), Escherichia coli ATCC 25933 (G-ve), and Candida albicans ATCC 10231 (yeast) (fungus). In order to strongly immunise nutritional agar plates against bacteria and yeast, 0.1 ml of 105-106 cells/ml were used each time. Potato dextrose agar plates seeded by 0.1ml (106 cells/ml) the fungal inoculum was used to calculate the antifungal activity. The vaccine plates were covered with textile-treated discs (15 mm in diameter). To allow for maximal diffusion, plates were then maintained at a low temperature (4°C) for 2-4 hours. The plates were then incubated for the bacteria at 37° C for 24 hours and for the organisms to develop as much as possible at 30° C for 48 hours in an upright posture. The diameter of the inhibition zone, stated in millimetres, was used to measure the test agent's antimicrobial activity (mm). The experiment was run many times, and the average reading was recorded. [6, 20, 26]

2.3.3. Measurements of self cleaning finishing

The breakdown rate of methylene blue was used to assess the photocatalytic efficacy of both pre- and post-treated polyester (Aldrich, United States). A Cary Varian 300 ultraviolet-visible (UV-Vis) spectrophotometer was used to quantify the amount of ultraviolet radiation that penetrated textiles between the wavelengths of 320 and 400 nm. By monitoring the breakdown of methylene blue under visible light at wavelengths higher than 410 nm, the photocatalytic self-cleaning capability was characterised. A fluorescent lamp (TC-L18W, AC230V-50 Hz, China) was used to provide visible light illumination at a distance of 5 cm and a light intensity of 44 W cm2). To create an equilibrium between photocatalysis and methylene blue adsorption/desorption under ambient conditions, a sample of 1 g was agitated for 30 min in 50 ml of an aqueous solution of methylene blue (10 mg/L at pH 6.5). [14, 27-29] After then, the sample was irradiated with visible light. A sample of roughly 5 mL of solution was obtained after each irradiation interval time, and it was analysed using a spectrophotometer. By measuring the absorption maxima at 665 nm as a function of the irradiation period, the concentration of methylene blue was determined. The following equation was used to measure the photocatalytic degradation: [27]

Photocatalytic degradation = $C_o - \frac{C_t}{C_o} = A_o - \frac{A_t}{A_o}$

Where A0 is the initial absorption, C0 is the starting methylene blue concentration, Ct is the concentration at various irradiation times, and At is the variable absorption at various irradiation times.

2.3.4. Measurements of UV protection

The UV protection factor (UPF) was calculated using the AS/NZS 4399:196 recommended method. AATCC 183:2010 UVA Transference was used to measure the ultraviolet diffusion through the cloth using a Cary Varian 300 UV-Vis spectrophotometer. [18, 30]

2.3.5. Measurements of contact angle

On the OCA-15EC (Data physics GmbH, Germany), water contact and sliding angles were monitored using software. With 10 L of triple-distilled water, contact angle qualities were tested. To form a flat surface, the substrates were attached to glass cover slips using double-sided adhesive tape. [7, 9, 11]

3. Results and Discussion

3.1. Antimicrobial finishing

Zinc oxide nanoparticles have special features that may be used to create textiles with self-cleaning and antibacterial capabilities, including photocatalytic, electrical, optical, dermatological, and antimicrobial properties. So Zinc Oxide is bio-safe and biocompatible for use in medical textile. ZnO-treated textiles can prevent the growth of germs because the hydroxyl radical and hydrogen peroxide can enter bacterial cell membranes and kill them. Additionally, the Zn2+ ions' interaction with the negatively charged cell surface of the microbe changes the cell's permeability, which alters the microorganism's normal metabolism and ultimately causes its demise. [4] **Table (1)** Represents the results of fabric coated with 0.1 ZnO NPS concentration.

Table 1. ZnO coating's antimicrobial effectiveness against a variety of test organisms including yeast (C. albicans), fungi, G+ve bacteria (S. aureus), and G-ve bacteria (E. coli) (A. niger).

Clear zone (ϕmm)	Staphylococcus aureus	18
	Escheichia coli	0
	Candida albicans	20
	Aspergillus niger	12

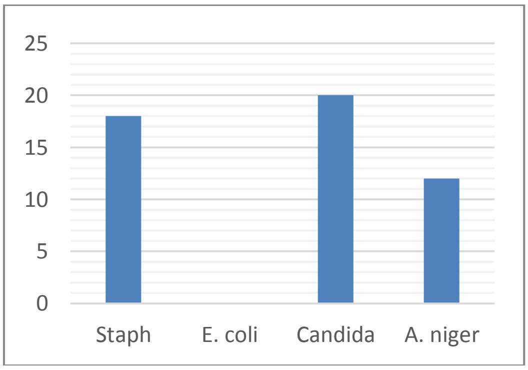
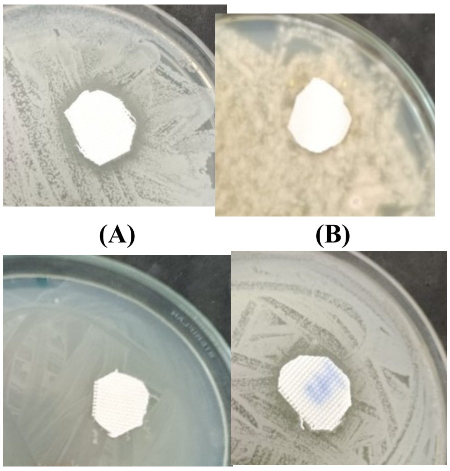


Figure (1). Antimicrobial activity of ZnO coating against different test microbes.



(A) **(B)**

(C) **(D)**

Figure (2). Photos of antimicrobial test in which **(A)** represents A. niger. **(B)** represents C. albicans. **(C)** represents E.coli. **(D)** represents S. aureus.

3.2. Self-clean finishing

The capacity of metal oxide nanoparticles to turn absorbed light into compounds that can self-clean and remove stains is one of the treatment's key characteristics. The pre- and post-treatment of polyester samples led to the development of a thin coating of nanoparticles that might enhance the hydrophobic characteristics of the fabric surface. The typical self-cleaning process used by metal oxide NPs combines an initial photocatalysis with a subsequent hydrophobic step.

Metal nanoparticles (NPs) exposed to UV radiation release free electrons that interact with oxygen and water molecules in the atmosphere to form free radicals. The organic stuff that contaminates the cloth surface can be broken down by those free radicals. The fabric surface may then be cleaned of any surface debris using water because of the hydrophobic effect created by the metal oxide nanoparticles on the fabric surface. [31-34] **Table (2)** shows the results of self-cleaning tests of treated fabrics .

Table 2. Screening for Self-cleaning results at different ZnO NPs concentrations.

Conc. Of ZnO NPs	0.05 g/l	0.1 g/l	0.15 g/l
Self cleaning value	96	110	136

3.3. Morphology and chemical composition properties

SEM was used to examine the surfaces of the polyester textiles that had not been treated, as shown in Figure (3). The nano-structures of the ZnO NPs (0.1g/l concentration) were examined by SEM examination. According to the particle size in the SEM picture, it was demonstrated that zinc interacted with oxygen at the nanoscale.

Analyzing the scanning electron microscope pictures closely revealed that the treated samples had particles with an average size of around 1000 x to 1 kx..

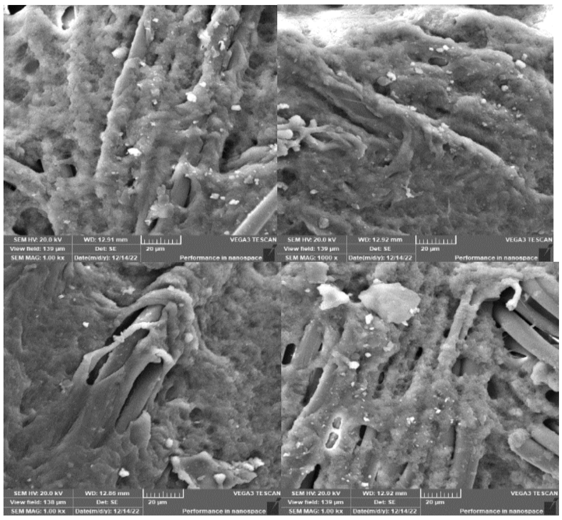


Figure (3). Scanning electron microscopy (SEM) of the fabrics treated with ZnO NPs

3.4. UV protection

By increasing the concentration of ZnO NPs, the effect of ultraviolet protection increases on the treated fabrics, as shown in **Table (3)**

Table 3. Self-cleaning results at different ZnO NPs concentrations.

Conc. Of ZnO NPs	0.05 g/l	0.1 g/l	0.15 g/l
UPF value	102	141	186

3.5. Contact angle test

It was discovered that silicone rubber treatment enhanced the fabric's water contact angle. [35] **Figure (4)** shows the results of the static contact angle measurements, as contact angle left is 133.8 and contact angle right is 133.8.

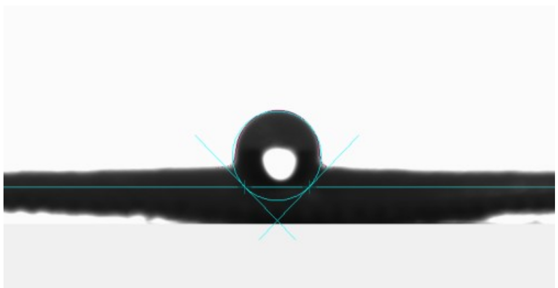


Figure (4). The result of the static contact angle of treated polyester fabric with Silicone rubber.

4. Conclusion

In conclusion, we have prepared a multifunctional Polyester fiber to suit the main purpose of our research. The treated polyester fabric with ZnO NPs demonstrated high antimicobial activity . At the same time the treated polyester fabrics have high self cleaning effect and good ultraviolet resistance. In addition to preparing it with silicone rubber, it has become highly water-repellent. Moreover, the polyester fabrics was finished using eco- friendly treatments, cost effective, and fits the main purpose of our research, which is a wheelchair for disabled children.

Conflict of Interest

There is no conflict of interest in the publication of this article.

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التجهيز المضاد للميكروبات، التنظيف الذاتي ، الحماية من الأشعة فوق البنفسجية والطارد للماء لأقمشة البوليستر للأطفال مستخدمي الكرسي متحرك

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المستخلص:

يمثل العمل الحالي تأثيث الكراسي المتحركة من أجل تطوير الأثاث الجلدي المعتاد ، حيث يمكن طباعته وإعداده لخدمة الأطفال المعاقين لأنه يحافظ على المياه ، ويقلل على المدى الطويل من الطاقة وتكلفة الغسيل والوقت أيضا ، كما أنه يزيد من مقاومة الرطوبة ، بالإضافة إلى الجماليات. تم معالجة نسيج بوليستر نقي بجسيمات أكسيد الزنك النانوية بالإضافة إلى مزيج من مطاط السيليكون والهكسان ، للحصول على التشطيبات المطلوبة للتنظيف الذاتي والمضادة للبكتيريا والأشعة فوق البنفسجية ، فضلا عن مقاومة النسيج للماء. تم اختبار العينات النهائية وتشير النتائج التجريبية إلى تضمين جميع القياسات المطلوبة ومناقشتها بالتفصيل.

الكلمات الدالة: أكسيد الزنك ، جزيئات النانو ، الاشعه فوق البنفسجيه ، مطاط السيليكون ، الهكسان.