

# Effect of Nano TiO<sub>2</sub> Finish on Functional Performance of Fabric

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**ABSTRACT:** Nanotechnology has not only exerted its influence in making versatile fibres but also has made an impact in making upgraded chemical finishes. It can provide high durability for fabrics since nanoparticles have large surface area to volume ratio thus presenting better affinity for fabrics. In present study Nano TiO<sub>2</sub> (<100nm) particles procured from Sigma Aldrich Company characterized and its application on cotton polyester/cotton and polyester viscose fabrics have been studied for improving functional performance of sport fabric. Nano TiO<sub>2</sub> applied on fabric with different concentrations. UV protection, antimicrobial and self-cleaning properties improvement has been found. The effectiveness of the treatment is assessed using standardized tests. It is found that the performance of TiO<sub>2</sub> nanoparticles as UV blocker and self-cleaning agent and antimicrobial agent can be efficiently transferred to fabric materials through the application of TiO<sub>2</sub> nanoparticles, which be useful for sport fabric.

## I. INTRODUCTION

Nanotechnology creates structures that have excellent properties by controlling atoms and molecules, functional materials, devices and systems on the nanometer scale by involving precise placement of individual atoms of the size around 0.1-100nm. The unique and new properties of nanomaterials have attracted scientists and researchers of the textile industry. Hence, the research interest for the use of nanotechnology in the textile industry has increased rapidly. This is mainly due to deploying nanotechnology. Fibres provide optimal substrates where a large surface area is present for a given weight or volume of the fabric. The synergy between nanotechnology and textile industry uses this property of large interfacial area and a drastic change in energetic is experienced by macromolecules or supramolecular clusters in the vicinity of a fibre when changing from a wet state to dry state[1].

The application of nanoparticles to textile materials has been the object of several studies, aimed at producing finished fabrics with different functional performances. For example, nano silver has been used for imparting antibacterial properties, nano ZnO for antibacterial and UV blocking properties[2]. Metal oxide nanoparticles are more preferable than nano silver because of cost consideration. In fact, TiO<sub>2</sub> and nano ZnO are non toxic and chemically stable under exposure to high temperature and are capable of photo-catalytic oxidation[3,4]. Furthermore, nanoparticles have a large surface area to volume ratio that results in a significant increase of the effectiveness in photocatalytic oxidation activity when compared to bulk materials [5]

Conventional textile finishing methods used to impart different properties, such as water repellency and stain repellency, to the fabrics often do not lead to permanent effects, and lose their functions after laundering or use. Nanoparticles can provide high durability of the desired textile functions. By virtue of its small size and high surface energy, nanoparticles are bound to the fabric surface by Vander waals forces which give a reasonable wash fastness[5]. Conventional Titanium is available in the form of titanium oxide, titanium dioxide and titanium trioxide, titanium pentaoxide. Titanium is a low density, highly corrosion resistant, lustrous white transition element. About 95% of titanium, production is consumed in the form of titanium dioxide. TiO<sub>2</sub> photo catalyst, find application in the purification of Water, Air, dye degradation and in materials processing functional characteristics such as anti bacterial and self-cleaning[4]. TiO<sub>2</sub> is an n-type semiconductor oxide photocatalyst. Among many photocatalysts TiO<sub>2</sub> is the only material suitable for industrial use because of it's -

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- High photo catalytic activity
- Chemical and photo stability
- Non –toxicity
- Resistance to photo corrosion
- Low cost

The other semiconductor oxides generally have less photo activity than  $\text{TiO}_2$  and some have problems associated with stability and reactivity.  $\text{TiO}_2$  in its nano crystalline form constitutes an enormously important commercial product, when the crystalline size is  $\leq 100\text{nm}$ . The reflectance of visible light decrease and the material becomes more transparent and exhibits a pronounced absorption of ultraviolet radiation [6].

The bulk  $\text{TiO}_2$  is opaque but nano  $\text{TiO}_2$  due to its transparency finds application in textiles that do not blur colors and brightness of these substrates. Since  $\text{TiO}_2$  has high UV absorption and concurrent high transparency for visible light, it finds widespread use in diverse areas as sun cosmetics, packaging materials and wood protection coatings<sup>1</sup>. characteristics,  $\text{TiO}_2$  could be one of the most important nanomaterials in future research and applications.

## II. RELATED WORK

Functional properties of fabric requires for sport fabric Properties (Track suits) are

- UV Protection Property
- Antimicrobial Property
- Self-Cleaning Property
- Sweat Absorbing Property i.e. wicking behavior

With the unique characteristics,  $\text{TiO}_2$  could be one of the most important nanomaterials in future research and applications. In present study weft knitted fabric is selected as it is having wide application in sports clothing. Type of structure affects UV affects blocking property so it is important to see its effect on knitted fabric. Antimicrobial property is important for sport wear to avoid microbial attack. In present study nano  $\text{TiO}_2$  used for finishing applied through pad dry cure process. The present study addresses the characterization of purchased nano  $\text{TiO}_2$  from Sigma Aldrich company, and evaluate its effectiveness for improving functional performance of sports fabric (like Track suit).  $\text{TiO}_2$  nanoparticles were applied on to cotton, Polyester cotton blended, and Polyester viscose blended fabrics [8]. As nano  $\text{TiO}_2$  enhances UV blocking effect antimicrobial property hydrophilic effect to fabric. This Nano finish is used for sports clothing for improving functional performance.

## III. MATERIALS AND METHODS

### Fabric

Mill bleached Knitted fabrics 1x1 Rib structure with 100Percent Cotton, Polyester cotton blended (35/65) and polyester viscose blended (38/62) were procured from Maral Overseas Ltd. Khargone. The fabric was further thoroughly washed, neutralized and air dried.

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**Table 1 Characteristics of knitted fabric**

Knitted Fabric	100Percent Cotton	PC blended	PV blended
<b>Coarses/cm</b>	16	16	16
<b>Wales/cm</b>	11	11	11
<b>GSM of fabric</b>	170	170	150

### Chemicals

Nano TiO<sub>2</sub> particles procured from Sigma-Aldrich Chemical Company, USA. Particle size was <100 nm. Surfactant Lissapol L., Nutrient Broth, M 002, Nutrient agar M 001 (all are Microbiology grade) and Staphylococcus Aureus (ATCC-6538 grade) and Escherichia Coli (Lab collection) bacterium colonies were used. Standard K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> (0.25 N), H<sub>2</sub>SO<sub>4</sub> reagent, Standard ferrous ammonium sulfate, Mercury sulfate crystals and Ferroin indicator solution were used.

### Methods

#### Preparation of nano solution with different concentrations.

For 1 gpl concentration, 0.1gm of nano-particles was added with 0.5 gm Lissapol L surfactant. The mixture was then stirred on magnetic stirrer at 500 rpm for 2hrs. Likewise all concentration solutions were prepared. Distilled water was used for preparing the solution of all the chemicals.

#### Characterisation of Nano TiO<sub>2</sub>

For analysis of morphology of Nano TiO<sub>2</sub> particles deposited on carbon coated aluminium sheet and further dried, which were then observed on scanning electron microscope (SEM) (Model JSM5610LV, version 1.0, Jeol, Japan) using oxford –Inca software(U.K.).

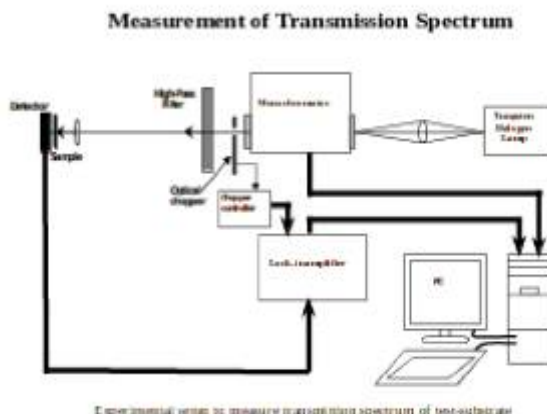
#### Treatment of textiles with Nano TiO<sub>2</sub> particles

Nano TiO<sub>2</sub> particles were applied to the cotton, PC and PV blended fabric samples by immersing them in the dispersion for 10 min and then padded on a padding sequence at 70Percent expression followed the same for two times (2 dip-2 nip). The padded fabric samples of 100Percent cotton and PC blended were dried at 80<sup>0</sup>c for 4 min and finally cured at 140<sup>0</sup>c, and PV blended fabric cured at 100<sup>0</sup>c for 3 min.

#### Determination of fabric Properties

#### Evaluation of UV transmissionPercent-

To determine the UV transmission percentage, instrument was fabricated in laboratory as shown in figure below. It gives the UV transmission percentage value in short time. The sample size required is 4 x 4 cm<sup>2</sup>



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The instrument was based on direct optic principle. UV radiations were generated through a tungsten halogen lamp ranging from 280-400nm wavelength as shown in figure 3.3(b). The light passes through the monochromator input slit of grating and 'Range of grating' is 0-1500 nm at 0.2 nm resolutions. The output from diffraction grating of monochromator is a continuous light beam. Optical chopper converts this light into pulses. The AC light passes through the concave mirror to focus the light, the use of concave mirror gives spherical wavefront, and to convert it back into the plane wavefront, plane mirror has placed. Thus, the light is directed towards the sample. From this the light passes on the fabric where the transmitted light detected by a UV diode. A lock in amplifier used to measure the photo current. The fabric sample was placed at 0.05cm away from the UV diode. The whole set up was programmed on the computer by the Labview 7.1 software. The computer screen directly shows the graph between wavelength and transmittance percentage calculated by the following formula:

$$\text{U V Transmission Percent} = \frac{\text{Trans. of UV rays obtained by fabric}}{\text{Trans. of direct UV rays}} \times 100$$

### Evaluation of Antimicrobial Activity

Test was based on ASTM E-2149 Method. Antimicrobial test of nano TiO<sub>2</sub> treated fabric carried out with gram-positive Staphylococcus aureus and gram-negative Escherichia coli bacterium.

Selection of bacterium is very crucial, as it is infectious for human beings.

Sample size: 1×1 inch<sup>2</sup>

Nano TiO<sub>2</sub> treated and untreated samples were kept separately into two 50ml conical flask containing 10 ml of liquid culture (Luria Broth) in which 0.1ml of microbial culture is inoculated in laminar flow.

All the closed flasks stirred with shaker incubator for four hours at 200rpm.

The inoculated test cultures with treated and untreated samples were tested by UV spectrophotometer for optical density measurement. Optical density of inoculated culture of treated sample was found very low as compare to inoculated test culture with untreated sample. Lower the optical density means lower is the growth or very low growth of bacterium and vice versa. In this way from the optical density readings, the percent reduction in growth of bacteria per ml of bacterial culture was calculated.

The percentage reduction in bacterial growth was calculated using the following equation –

$$\text{Percent Reduction of bacterial growth} = \frac{(B - A)}{B} \times 100$$

Where, A is the optical density for the inoculated test culture of containing the treated sample.

B is the optical density for the inoculated test culture of containing the untreated sample.

### Evaluation of Self-cleaning action

The measured quantity of 6% coffee solution was applied on the cotton fabric and allowed to spread. One-half portion of each stain on the fabric was exposed to sunlight for 12 hours while the other half portion was covered with a black paper to prevent its irradiation from sunlight. The exposed part of the stain compared with the unexposed portion for self-cleaning action. The stained samples were assessed for color differences [ΔE] and K/S values (illuminant D65/100 observer) on Spectra scan 5100 (RT) spectrophotometer (premier colorsan instrument). The self-cleaning action can quantify by comparing the K/S values of the exposed and the unexposed portion of the same stain.

The K/S value of the unexposed part of the stain taken as 100 and the relative decrease in the K/S value of the exposed part can calculate using the following relation.

$$\% \text{ Decrease in K/S value} = [(K/S \text{ Unexposed} - K/S \text{ Exposed}) \div K/S \text{ Unexposed}] \times 100$$

### Tensile Strength Test

The breaking load (Tensile strength) of the samples was determined on tensile strength tester instrument (Model-Lloyd, LRX, U.K.)

### Wicking Test

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Test was based on T-PACC standard method.

The test samples were prepared with 17cm and 2.5cm width in coarse wise direction. One end of the sample has suspended vertically, on the support behind the scale with the help of a clip. The load was attached to the other end of the specimen. A 5gm hanging weight was loaded on the fabric to keep it under tension. Higher than this weight can close the capillaries and inhibit flow through the fabric. The reservoir (Measuring cylinder) was filled to 300ml with tap water. The sample was immersed in a reservoir of water up to 3mm mark from the bottom edge of the sample. In each test, observations of water column were made for 1min, 5min and 10min. Five tests were conducted for each sample. For particular specimen the average of five readings has taken into account. In this way, wicking behavior of treated and untreated samples evaluated.

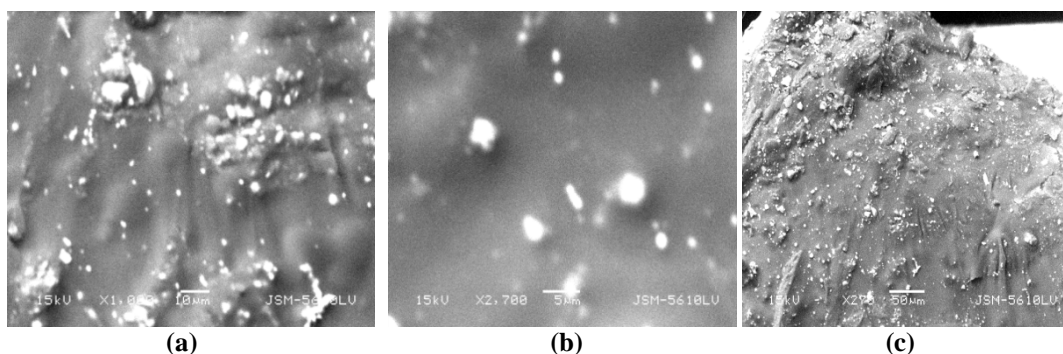
### COD-Chemical oxygen demand

COD represents the oxygen required to chemically decompose the pollutant. The COD test is used exclusively in the analysis of industrial wastes. In addition, it is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. In experiment, the organic matter is completely decomposed to CO<sub>2</sub>, H<sub>2</sub>O and oxides. Organic matters are destroyed by a boiling mixture of chromic and sulfuric acids. A sample is refluxed with known amounts of potassium dichromate and sulfuric acid. The excess dichromate is measured as oxygen equivalent. In this way toxicity of Nano TiO<sub>2</sub> effluent tested.

## III. RESULT AND DISCUSSION

### Characterisation of nano TiO<sub>2</sub> particles

The particle size and shape were analysed on scanning electron microscope. Referring to Figure 1 (a, b, c), nano particle size is seen to be about less than 100nm. Many particles are seen in agglomerated form and size found to be about 2000nm.



### Characterization of nano TiO<sub>2</sub> coated fabrics

Referring to Figure 2(a, b) [SEM image of Cotton surface treated with 10 grams/liter nano TiO<sub>2</sub>], nano TiO<sub>2</sub> particles present in the fabric matrix are of about 1000nm size, actual nano particles are not seen here, due to the agglomeration of particles at many places at the high concentration of nano-solution and may be due to the error in handling nano particles during preparation of nano solution

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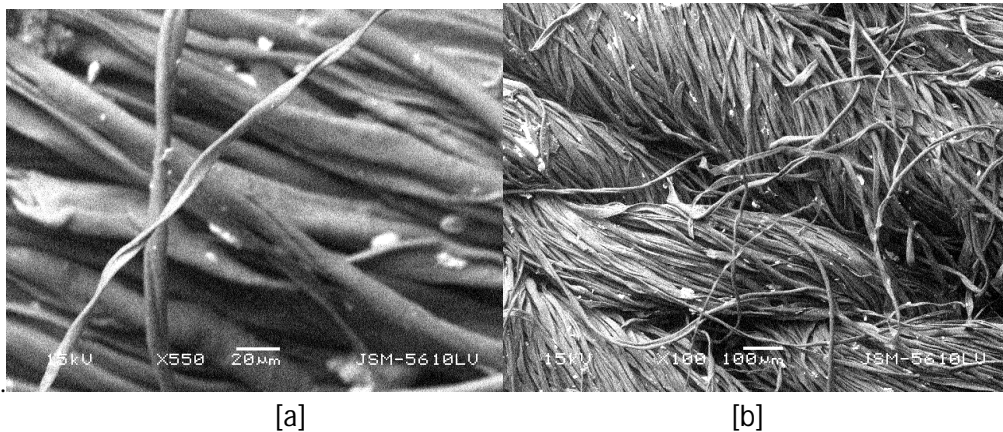


Figure 2 (a, b) Cotton fabric treated with 10gpl Nano TiO<sub>2</sub>

From Figure 2 (c,d) [SEM image of surface treated with 5grams/liter nano TiO<sub>2</sub>], nano TiO<sub>2</sub> particles are found uniformly distributed with less agglomeration as compared to 10gpl concentration.

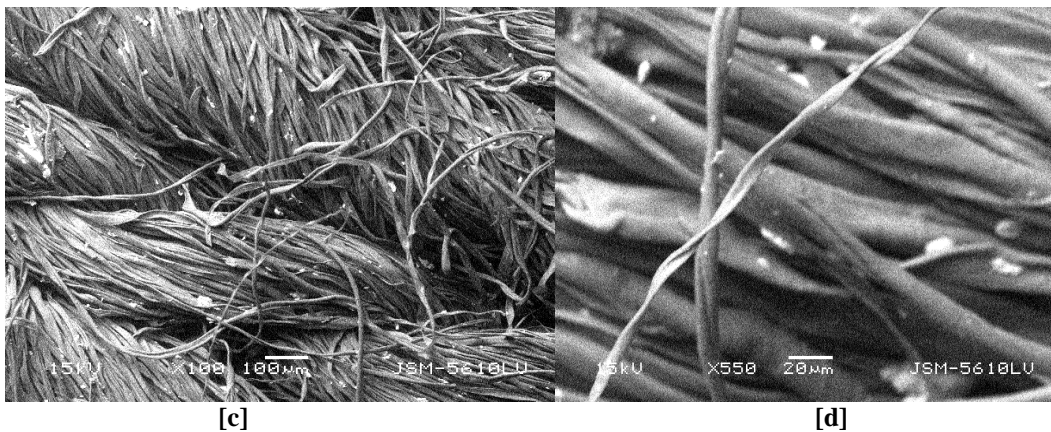
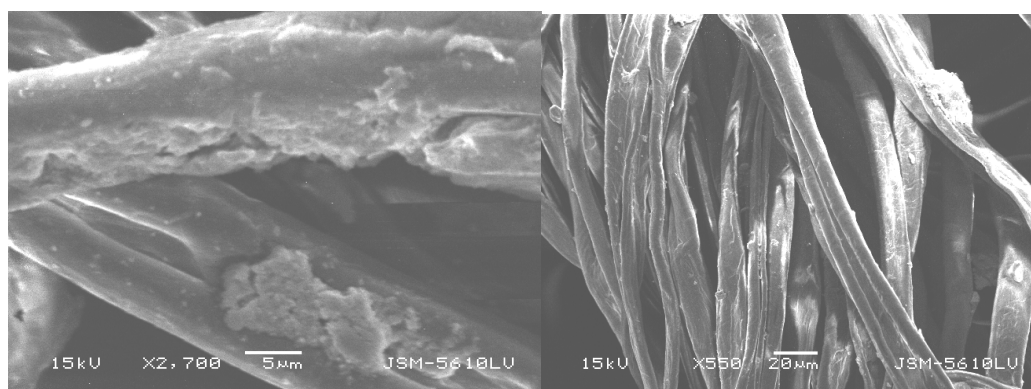


Figure 2 (c, d) Cotton fabric treated with 5gpl Nano TiO<sub>2</sub>

From Figure 2 (e, f) [SEM image of PC blended surface treated with 5 grams/liter nano TiO<sub>2</sub>], nano particles distribution is found to be uniform as compared to cotton fabric with 5 gpl concentration. Some agglomeration is seen in SEM image.



(e) (f)  
**Figure 2(e,f) PC blended fabric treated with 5 gpl Nano TiO<sub>2</sub>**

**UV transmission Percent analysis**

Table 2 and figure3(a) shows [100Percent cotton fabric], UV transmission percent through fabric decreases as the concentration of nano TiO<sub>2</sub> increases i.e. better UV protection is obtained as compared to untreated fabric. At 1gpl, 3gpl there is no significant improvement in UV protection of fabric. The reason may be of insufficient number of nano particles present on the fabric.

Table 2 and figure3(b) shows [PC blended fabric], UV transmission Percent through fabric decreases as the concentration of nano TiO<sub>2</sub> increases i.e. higher is the concentration of nano TiO<sub>2</sub> better is the UV protection. At 1gpl, 3gpl there is no significant improvement in UV protection of fabric. The reason may be of insufficient number of nano particles present on the fabric.

Table 2 and figure3(c) shows [PV blended fabric], the trend of result is same as for cotton in protecting fabric from UV transmission i.e. higher the concentration better was the UV protection.

It is evident that the application of nano sized particles on all fabrics increases UV absorbance in the region between 300nm and 400nm. There is around 50% UV shielding as compare to untreated samples in case of 100 % cotton fabric and PV blended fabric at 10gpl concentration. In PC blended fabric there is around 32% improvement this may be due to the agglomeration of particles this can be observed in SEM images fig 2 (e, f). At other concentration levels, the similar trend though with varying percent improvement is noticed. This effect can further be enhanced by using a different procedure for the application of nanoparticles on to the fabric surface. When the process of padding is used for applying the nanoparticles on to the fabric, the nanoparticles are applied not only on the surface alone but also penetrate into the fabric interstices of the yarns and the fabric, i.e. some proportion of the nanoparticles may get penetrated into the fabric structure. Such nanoparticles, which do not stay on the surface, may not be very effective in shielding the UV rays. In addition, Raleigh's scattered theory supports the result for UV shielding there should be proper size of nanoparticles for particular wavelength.

**Table 2 UV transmission percent Summary Results**

Fabric Sample	Cotton (% Transmission)		PC blended (% Transmission)		PV blended (%Transmission)		
	UV -A	UV-B	UV-A	UV -B	UV -A	UV-B	
Untreated sample	21.50	21.60	22.05	23.10	23.48	23.64	
Nano TiO <sub>2</sub> Treated sample	Conc. (gpl)	(+ improvement in UV transmission %)					
	1	17.72(+18)	17.87(+17.26)	20.65(+7)	20.72(+10.30)	22.43(+4.8)	22.50(+5)
	3	17.54(+18.41)	17.57(+18.6)	20.18(+9)	20.24(+12.38)	21.53(+8.3)	21.63(+8.5)
	5	16.29(+24.2)	16.20(+25)	18.70(+15)	18.83(+18.48)	20.80(+12)	21.67(+8.4)
	7	12.62(+41)	12.70(+41)	18.61(+15.60)	18.36(+20.52)	18.26(+22.23)	18.4(+22.16)
	10	11.19(+48)	11.08(+45)	15.66(+29)	15.67(+32)	11.57(+50.72)	13.30(+44)

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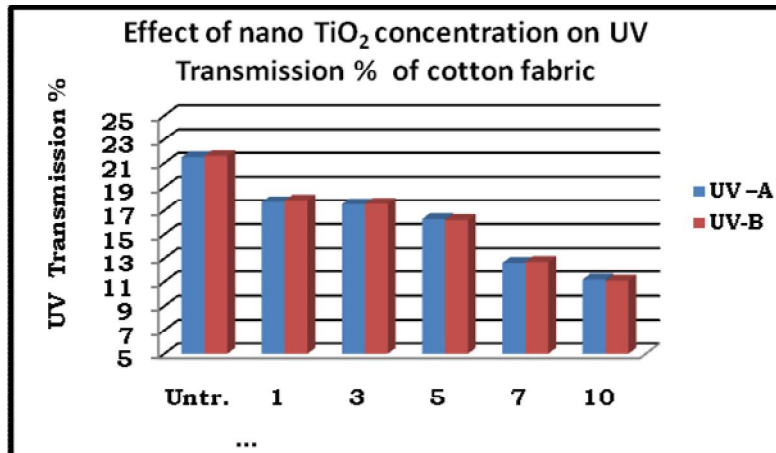


Figure 3(a)

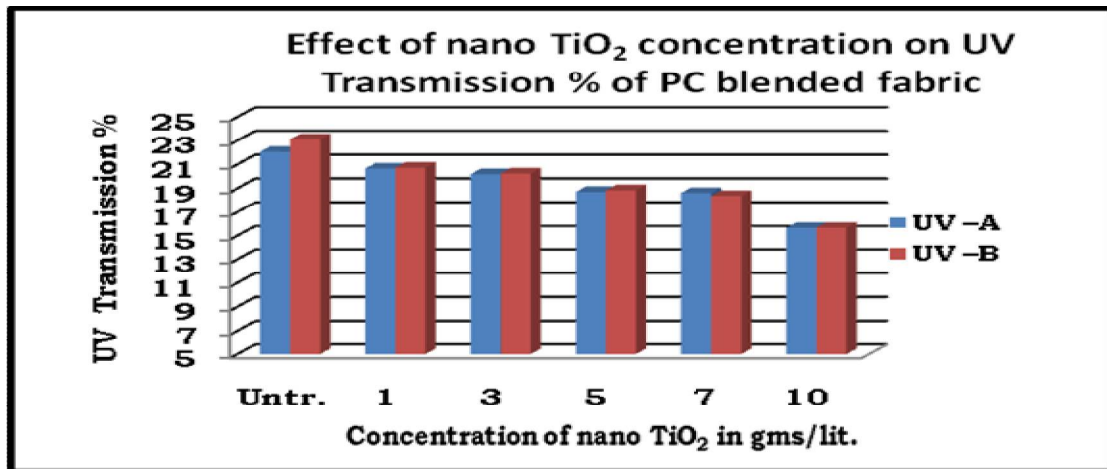


Figure 3(b)

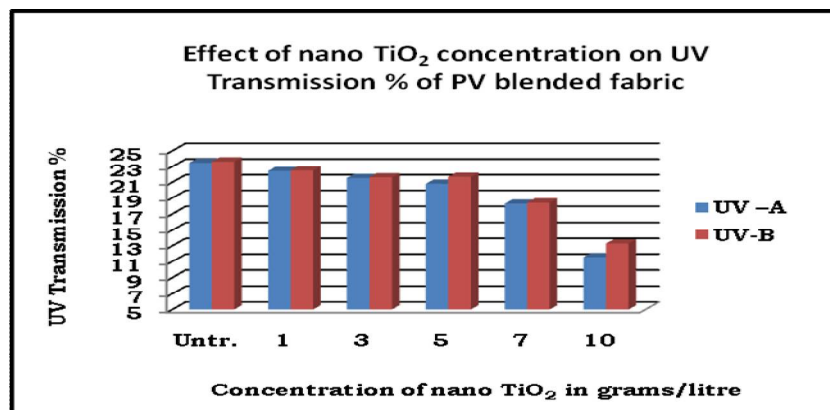


Figure 3(c)



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### Self-cleaning action analysis

Table 3 [cotton fabric], it is found that higher is the concentration of nano TiO<sub>2</sub>, higher is the self-cleaning action. At 3gpl, concentration there is abrupt improvement in self-cleaning action, this may be the experimental error. More is the percentage decrease in K/S value, more the stain removal capacity.

Table 4, [PC blended fabric], it is observed that, there is deterioration in self-cleaning action at higher concentration than 5gpl. This may be due to the agglomeration of nano particles on the surface at higher concentration. Polyester fibre has more crystalline region (~90%); so particles may remain on the fibre surface in agglomerated form at higher concentration, which may not contribute in self-cleaning action this we .

From Table 5, [PV blended fabric], it is found that, higher the concentration of nano TiO<sub>2</sub>, higher is the self-cleaning action. This may be due to the high absorbency of viscose fibre; there is higher depth of coffee stain. This requires higher concentration of nanoTiO<sub>2</sub> for better self-cleaning action.

**Table 3 Effect of concentration of nano TiO<sub>2</sub> on Self-cleaning effect of cotton fabric**

Nano TiO <sub>2</sub> Conc. (gpl)	K/S of Treated sample (Exposed)	K/S of Treated sample (Unexposed)	Decrease in K/S (%)	K/S of Untreated sample (Exposed)	K/S of Untreated sample (Unexposed)	Decrease in K/S (%)
1	0.50	0.70	28.5	0.35	0.49	28
3	0.93	1.73	46.13	1.273	1.763	28
5	1.62	2.35	31.2	1.273	1.763	28
7	1.64	2.61	36.89	1.273	1.763	28
10	0.66	1.29	48	1.273	1.763	28

**Table 4 Effect of concentration of nano TiO<sub>2</sub> on Self-cleaning effect of PC blended fabric**

Nano TiO <sub>2</sub> Conc. (gpl)	K/S of Treated sample (Exposed)	K/S of Treated sample (Unexposed)	Decrease in K/S (%)	K/S of Untreated sample (Exposed)	K/S of Untreated sample (Unexposed)	Decrease in K/S (%)
1	0.48	1.00	33.28	0.26	0.36	16.94
3	1.02	1.38	44	0.86	1.04	16.94
5	0.89	1.62	42.72	0.86	1.04	16.94
7	1.61	2.69	40	0.86	1.04	16.94
10	1.12	1.18	5.3	0.86	1.04	16.94

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**Table-5 Effect of concentration of nano TiO<sub>2</sub> on Self-cleaning effect of PV blended fabric**

Nano TiO <sub>2</sub> Conc. (gpl)	K/S of Treated sample (Exposed)	K/S of Treated sample (Unexposed)	Decrease in K/S (%)	K/S of Untreated sample (Exposed)	K/S of Untreated sample (Unexposed)	Decrease in K/S (%)
1	0.49	0.57	16.66	0.46	0.44	16.07
3	0.94	1.25	16.71	1.27	1.51	16.07
5	1.03	1.54	32.69	1.27	1.51	16.07
7	1.61	2.033	20.8	1.27	1.51	16.07
10	1.52	1.99	23	1.27	1.51	16.07

### Analysis of Effect of Nano TiO<sub>2</sub> on wicking behavior

From the Figure 4 [cotton fabric] and Fig 5[PV blended fabric], it is indicated that there is no major effect of nano TiO<sub>2</sub> on wicking behavior, may be because the nano particles do not affect any basic structure of fabric i.e. capillaries present in the fabric.

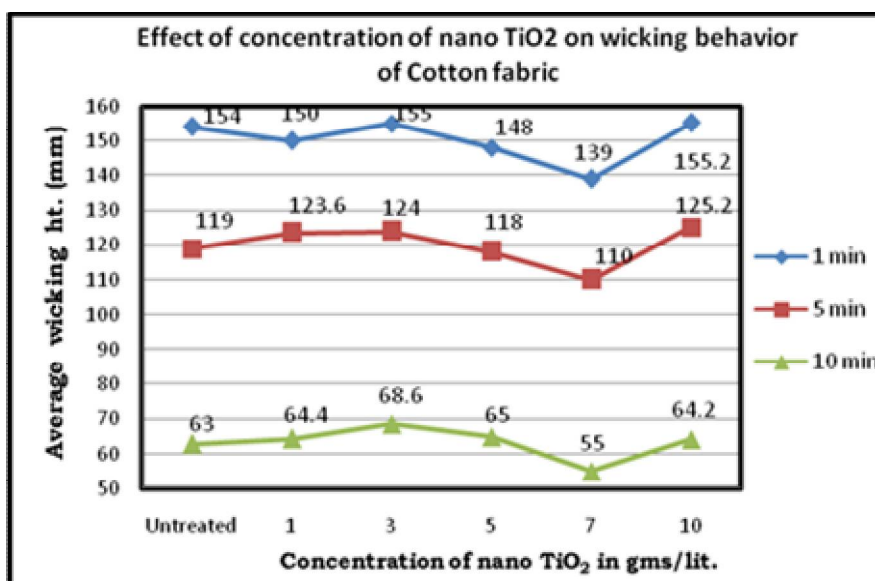


Figure.4

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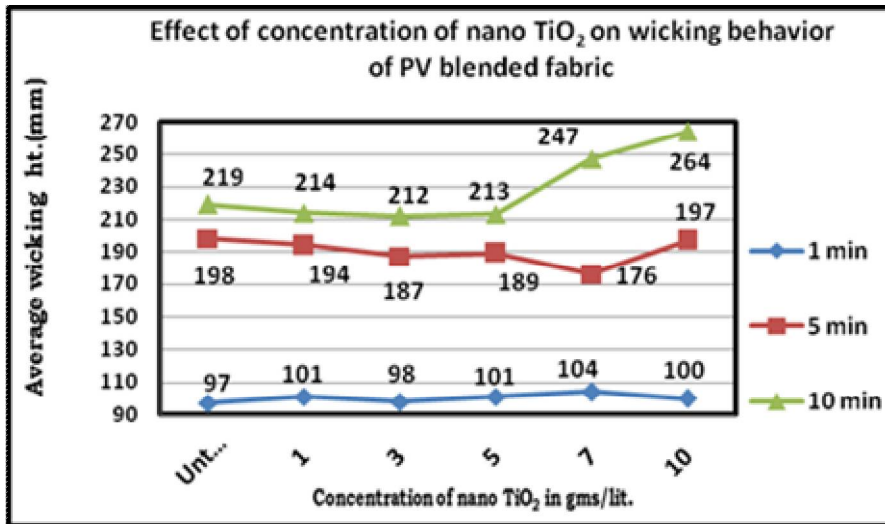


Figure.5

From Figure 6 [PC blended fabric], it is indicated that there is minor decrease in wicking behavior at 7gpl and 10 gpl concentration. This may be due to (~90%) crystalline region of polyester fibre, nano-particles remain on the surface of fibre in agglomerated form at higher concentration. This may be responsible for hindering the flow of water through the fabric matrix.

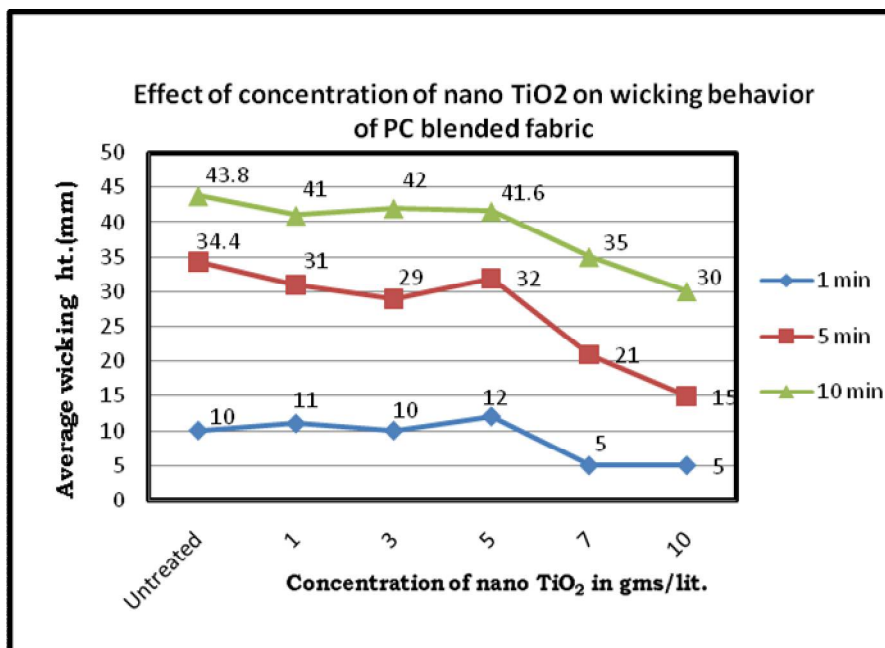


Figure 6

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### Analysis of Effect of Nano TiO<sub>2</sub> on Tensile strength of fabric

It is found that there is no loss in tensile strength of fabric.

### Analysis of antimicrobial property of fabric

Antimicrobial property tested against S.Aureus and E.Coli bacterium. From Table 6, Cotton fabric treated with all concentrations of nano TiO<sub>2</sub> is tested for antimicrobial property. There is consistent improvement in antimicrobial property of fabric found with S.aureus bacterium. Antimicrobial property is in increasing order with the increase in concentration of nano TiO<sub>2</sub> finish but there is no significant improvement found in antimicrobial property after 5gpl concentration. There is no effect of antimicrobial property with E.Coli bacterium.

**Table 6 Antimicrobial Activity of the nanoTiO<sub>2</sub> impregnated cotton fabric**

Sr. No.	Cotton fabric samples treated with nano TiO <sub>2</sub> (gpl)	Optical density of samples with S.aureus bacteria	Reduction of bacterial growth (%)
1	Untreated sample	1.50	No reaction
2	1	0.0742	95
3	3	0.062	96
4	5	0.037	97.50
5	7	0.028	98.13
6	10	0.008	99.46

From Table 7, in PC blended fabric, at 5gpl concentration there is 47Percent reduction in microbial growth with S.aureus bacterium, this is lower in comparison to percentage reduction in case of cotton fabric. There is no effect of antimicrobial property found with E.Coli bacteria.

**Table 7 Antimicrobial Activity of the nanoTiO<sub>2</sub> impregnated PC blended fabric**

Sr. No.	PC blended fabric sample treated with nano TiO <sub>2</sub> (grams/litre)	Optical density of microbial liquid culture with sample	Reduction of bacterial growth (%)
		S.Aureus	
1	Untreated Sample	0.380	No reaction
2	5	0.201	47Percent

From Table 8, in PV blended fabric at 5gpl concentration there is 36Percent reduction in microbial growth with S.aureus bacterium.

There is no antimicrobial reaction with E.coli bacterium with all three fabrics. Also the finding that Gram –positive bacteria are more susceptible to TiO<sub>2</sub> than Gram –negative bacteria [8] supports our results. Thus we concluded that nano TiO<sub>2</sub> have a bactericidal action effect on S.aureus and bacteriostatic action on E.Coli bacteria.

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**Table 8 Antimicrobial Activity of the nanoTiO<sub>2</sub> impregnated PV blended fabric**

Sr. No.	PV blended fabric sample treated with nano TiO <sub>2</sub> (grams/litre)	Optical density of microbial liquid culture with sample	Reduction of bacterial growth (%)
		S.Aureus	
1	Untreated Sample	0.312	No reaction
2	5	0.201	36Percent

### Analysis of Environmental impact of Nano TiO<sub>2</sub>

COD value of 5gpl concentration effluent solution found to be 44 which is less than standard value for COD. This result shows that nano TiO<sub>2</sub> applied on the fabric is non-toxic and not harmful to the environment, it does not require any effluent treatment.

### IV. CONCLUSIONS

1. SEM analysis result of nanoparticles confirm the size given by manufacturer but there is high variation in particle size may be due to agglomeration of particles. Nano TiO<sub>2</sub> particles found is of spherical shape.
2. UV transmission Percent result shows major improvement at higher concentration only.
3. There is consistent improvement in antimicrobial property with gram-positive bacterium i.e. S.aureus only there is no reaction of antimicrobial property with gram negative bacterium E.coli.
4. There is no deterioration in tensile strength of Cotton and PV blended fabric only in case of PC blended fabric there is deterioration at higher concentration.
5. There is no deterioration in wicking behavior of fabric.
6. In case of cotton fabric, higher the concentration of nano TiO<sub>2</sub> finish, higher is the self-cleaning action. In PC blended fabric there is deterioration in self-cleaning action at higher concentration this may be due to agglomeration of nano particles on polyester fibre this supports SEM image fig 2(e.f).
7. Finally it is concluded that Nano TiO<sub>2</sub> particles as found non-toxic can be useful for the sport fabric finishing for improving its functional performance.

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