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Investigation on the Performance of Self-Cleaning Activity for TiO_2 Treated Textile Fabrics and Laundry Effect on Their Durability

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ABSTRACT
In this study TiO_2 was used as a coating compound to impart self-cleaning capability of textile fabrics and analyzed its absorbency and water vapor comfort ability of treated fabrics at several times washing . TiO_2 solution of 1gm/100ml and 2gm/100ml were prepared with the binder and mixture was stirred at the sonicator for 30 min and applied by ossila spin coater on the single jersey knitted (cotton, Polyester-Cotton blend(65/35) and 5% grey Mélange) and woven (100% cotton and polyester)fabrics .The self cleaning ability of different fabrics were visually assessed after exposing under sunlight about 20hrs and also analyzed these samples appearance after sunlight exposure by value index of CIE L*A*B* color space in reflectance spectrophotometer The sample were prepared in consideration with different wash. The absorbency and water vapor permeability of treated samples were determined with respect to different wash. We have found that the self-cleaning ability of the fabric was convenient at the concentration 1gm/100 ml and it was appropriate for 100% cotton fabric only. With the increase of TiO_2 concentration the absorbency i.e spray rating grade decreased except for the fact Polyester woven fabric. The breathability is remarkably well even in the increased of concentration of TiO_2 and under different times of wash.

Keywords: Absorbency, Laundry Effect, Self-cleaning Performance, TiO_2 treated fabric, Water vapor permeability.

1. Introduction

For a long time it was matter of interest how to impart self cleaning property on textile materials because of its diverse usability and unique characteristics in the field of textile sector. The fabric surface to keep it clean against dirt, grease; oils and water for longer durations it is necessary to maintain low surface energy which can be acquired through Nano-coatings and alternative procedures. This has a potential to be used in various sectors and can enhance the quality of the product. The demand for sanitary, self-disinfecting and contamination free surfaces ,self-cleaning protective materials is increasing day by day in global market where the self cleaning technology can be utilized [1]. This self cleaning technology also can be used in various sectors like fabrics, furnishing materials, window glasses, and outdoor construction materials such as roof tiles, car mirrors, and solar panels [2].

Formally different type of materials like wax, silicones, polyfluorinated carbons and polyvinylchloride were used for introducing the self cleaning properties. However new technologies have been developed to improve the performance of self cleaning characteristics. In the modern age nanomaterials have been introduced as a coating material over the textile products for ameliorates the self cleaning properties of them [3-4]. Different methods like pad-dry-cure, knife coating, plasma treatment, etching, chemical vapor deposition and sol-gel method are used for applying the self cleaning materials on the surface of textile products.

In the modern era of science nano technology is showing a promising opportunity to take the current technology to the next step. Following that path different types of nano particles have been studied as the self cleaning materials. Among those nano materials titanium dioxide (TiO_2) has showed a very good self cleaning property in case of applying it on the surface of textile materials [5]. That is why the properties of titanium dioxide (TiO_2) has been studied extensively for make it even better as a self cleaning material. Titanium dioxide (TiO_2) has some properties like low cost, outstanding chemical stability, suit-able band gap, non-photo corrosive and non-toxic nature. In this study we have used titanium dioxide (TiO_2) to learn and understand the characteristics of it so that we can improve the current methods[6].

The main mechanism of the self cleaning properties of TiO_2 can be explained very profoundly. Sunlight plays a vital role in the process of self cleaning mechanism of TiO_2. When the sun light hit the TiO_2 layer which is deposited on the surface of the fabric, it helps the conduction band electrons to be get excited and react with the oxygen molecules in the air [7-8]. The double bond of the oxygen molecule is broken and in presence of oxygen and/or water, super-oxide (O_2-) and/or hydroxyl (OH-) radicals are formed, which attack adsorbed organic species such as stains or dirt on the surfaces of titanium dioxide nanoparticles layers deposited on the cotton fabric and decompose the polymeric textile materials, as well as the contaminants, which are mostly comprised of C-C, C-H, C-O,O-H and N-H bonds . [9,10,11].
Additionally the self-cleaning property can be accomplished by fabric modification in agreement with this necessity [12]. During finishing of TiO_2 nanoparticles on cotton fabric it is assumed that TiO_2 forms ester bonding over the non-homogeneous irregular structure of the cotton making it more self-cleaning, ultraviolet irradiation resistant and antibacterial in nature [13-14].

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Some studies recommended that similar properties could be achieved for polyester nonwoven structures coated with titanium dioxide nanoparticles when reactive sputtering methods are applied [15]. It will be more convenient if an easy route prepared in laboratory and/or in industry maintains such surfaces, for its endless applications [16-17].

The objective of this study is to investigate the influence of fabric structures (woven and knitted fabrics) on the efficiency of TiO_2 which was prepared by the addition of acrylic binder to impart a self-cleaning textile material that decomposes contaminants and stains on textile surface under sunlight. [18-19] Besides the analysis of photocatalytic oxidation of the treated fabrics, the water repellency and water vapor permeability were also tested to justify the quality of treated fabrics.

2. Meterails and Methodology

2.1 Materials

Raw woven plain weave 100% cotton fabric (GSM 140, count 30 Ne) , 100% polyester (GSM 160, count 30 Ne) , bleached knitted fabric of 100% Cotton (GSM 160, count 30 Ne) , PC (65% polyester, 35% cotton) , Mellange (5% dyed, 95% undyed) has been used in the experiment. In the experiment the cotton was bleached, and the polyester was hot washed. Chemical supplier provided Nano crystalline Titanium Di oxide (TiO_2) powder (Anatase) , acrylic binder and Acetic acid. Distilled water was purchased from a local chemical store in Khulna, Bangladesh.

Table 1 Fabric GSM and composition

Sample	Fabric Type	GSM	Composition
01	Polyester-cotton knitted fabric	160	Cotton: 65% Polyester: 35%
02	Cotton Knitted fabric	160	100% cotton
03	Mellange Knitted fabric	160	5%Grey Mellange
04	Cotton Woven fabric	140	100% cotton
05	Polyester Woven fabric	140	100% polyester

2.2 Methodology

2.2.1 Preparation of TiO_2 solution

100 ml water was taken into a beaker. Then 1gm/2gm of TiO2 was taken into that beaker. After that 1 ml acrylic binder was added in the solution. Then the mixture of TiO_2 binder and water were stirred manually to mix these particles uniformly. Then the mixture was further mixed and stirred with the help of ultrasonic sonicator for 30 min. After that the mixture forms a paste like solution that viscosity is kept very low to coat on fabric sample.

2.2.2 Application of TiO_2 solution on Textile materials with spin coater

The TiO_2 paste was applied on the fabric sample with the help of spin coater. The RPM of spin coater was 2400/s. A small amount of solution was taken into a digital pipet and spray slightly on the movement of spin coater. The 5×5 cm^2 sample was attached on the spin coater's sample board and rotated with RPM. The rotation time was about 30s.

2.2.3 Curing

Finally, the samples were cured by dryer at 130°C to fix the coated materials on the fabrics. The temperature was kept around 130°C because generally curing is done at 130-140°C.

2.3 Evaluation of treated sample

2.3.1 Spray rating test

Spray rating test is the process to determine the water repellency of the testing material with the help of shower test. At first the sample was cut. The dimension of the sample was 18×18 cm^2. The weight of the sample was measured. However it is not possible for spin coater to make a sample having the necessary dimension of 18×18 cm^2. There for the sample was made using padding method which shows similar kind of result as the spin coated samples. Then sample was placed on the hopper. The diameter was at 15 cm. The 250 ml normal water was poured from the funnel. It took almost 30 second for spraying in the sample. After that the weight of the wetted cloth was measured. The absorbency of the fabric was measured using the appropriate formula.

2.3.2 Water vapor transmission test

Water vapor transmission test is the process of measuring the passage of water vapor through a substance. In the water vapor transmission at first the sample was cut which has an area around 0.4 $feet^2$. Then the sample was put on the specimen holder which containing water. Then the sample was weighted in the balance box. After that the temperature of the tester was set to 32 degree and the Relative Humidity tester was kept at 57%. Then it was kept for 15 min. And after that the changes in the weight of the specimen was measured and Water absorbency of the sample was measured using the necessary formula.

2.3.3 Spectrophotometric Test

The spectrophotometric assessment of the fabric was done in the fabric to identify the self-cleaning activity of the fabric. In the assessment several picture was taken of the various treated and untreated fabric. The value of lightness, hue, Chroma, was measured.

Five samples of 100% Cotton (Knitted), PC, 5% Mellange, 100% cotton (woven), Polyester fabric has been tested and their spectrophotometric assessment was determined. The initial means which is untreated with TiO_2 and no wash means treated with TiO_2 but not washed. 1 wash means the TiO_2 is washed for 1^{st} time.

And the 2 wash means that the test is performed after 2nd wash.

3. RESULT AND DISCUSSION

3.1 Visual assessment of self-cleaning activity (Cotton, PC and mélange)(Conc. of TiO_2 1 gm. /100 ml)

Here three types of fabric 100% cotton knitted, PC and mélange fabrics were tested. The picture was taken after the application of tea on the fabric.

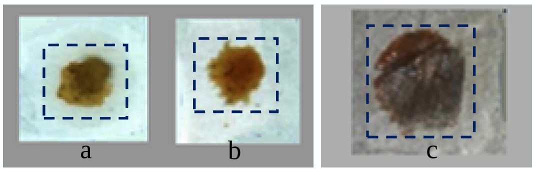

Fig.1 Tea stain on TiO_2 treated (a) cotton, (b) PC, and (c) mélange knitted fabrics

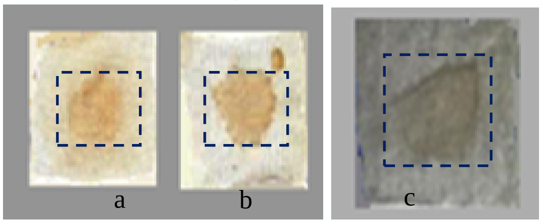

Fig.2 Appearance of Tea stain on TiO_2 treated (a) cotton, (b) PC and (c) mélange knitted fabrics after sunlight exposure

After exposure to the sunlight for 20 hours there was significant change in the tea stain in the sample. The change was clearly visible in the figure. Where we noticed that the stain accumulated in the cotton fabric almost vanished. Other fabric dirt was vanished but it was not noteworthy. The self-cleaning ability of 100% cotton fabric was better than other samples.This may due to ester bonding of TiO_2 with the non-homogeneous irregular structure of the cotton making it more self-cleaning [9,10].

3.2 Visual assessment of self-cleaning activity (Cotton, PC, mélange) (Conc. of TiO_2 2gm. /100 ml)

As like previous test, tea solution was poured same types of knitted fabrics which was treated with 1gm/100 ml conc.TiO_2 solution..

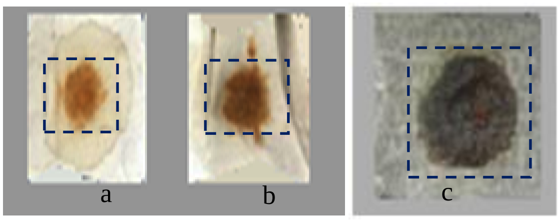

Fig.3 Tea stain on TiO_2 treated (a) cotton, (b) PC, and (c) mélange knitted fabrics

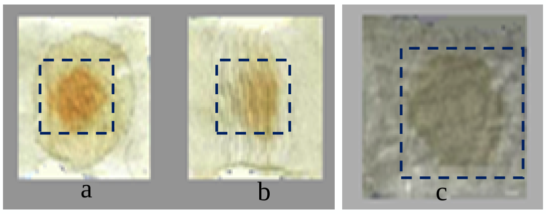

Fig.4 Appearance of Tea stain on TiO_2 treated (a) cotton, (b) PC and (c) mélange knitted fabrics after sunlight exposure

Then the sample was exposed into sunlight for 20 hour. After exposure to sunlight for 20 hour the following picture was taken. The self-cleaning capability of all knitted fabrics were more prominent at 2gm/100 ml treated TiO_2 than 1gm/100ml TiO_2 treated samples. Among three samples Polyester cotton blended sample visually seemed better than cotton sample after photocatalytic oxidation of the treated fabrics which needed to be clarified by spectrophotometric value .

3.3 Visual assessment of self-cleaning activity (100% Cotton and polyester woven fabric) (Conc. of TiO_2 1 gm. /100 ml)

To investigate the self cleaning performance of TiO_2 on woven fabric, two types of woven fabric such as cotton and polyester was taken and TiO2 paste (1gm/100 ml) was coated on the samples. After 20 hr of exposure on sunlight we observed the following changes:

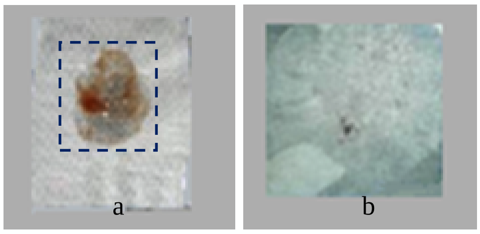

Fig.5 Tea stain on TiO_2 treated (a) cotton and (b) polyester woven fabrics

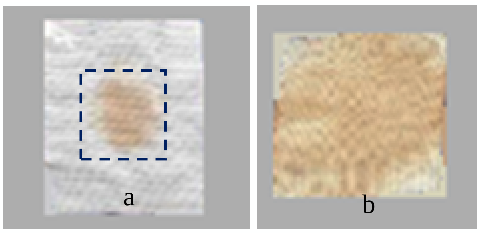

Fig.6 Appearance of Tea stain on TiO_2 treated (a) cotton and (b) polyester woven fabrics after sunlight exposure

In fig. 5 and 6, it was noticeable that the self cleaning efficiency of cotton woven fabric was higher than polyester fabric [9,10]. On the other hand the TiO_2 treated polyester fabric showed uneven surface view after sunlight exposure.

3.4 Visual assessment of self-cleaning activity (100% Cotton and polyester woven fabric) (Conc. of TiO_2 2 gm. /100 ml)

For further investigation the effect of TiO_2 concentration on the self cleaning capability of textile woven fabric we applied the 2gm/100ml TiO_2 solution on the cotton and polyester fabric. The sample was placed at sunlight as like previous process.

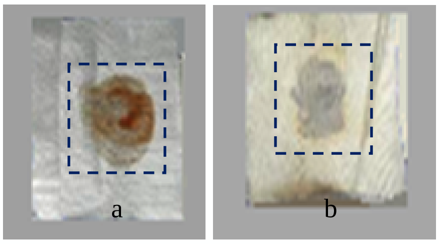

Fig.7 Tea stain on TiO_2 treated (a) cotton and (b) polyester woven fabrics

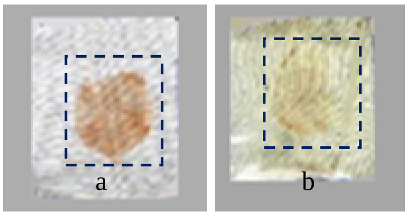

Fig.8 Appearance of Tea stain on TiO_2 treated (a) cotton and (b) polyester woven fabrics after sunlight exposure

During investigation it was clear that cotton fabric which self cleaning performance which was more even than polyester woven fabric.

3.6 Spectrophotometric assessment of self-cleaning activity

The value index L of CIE L*a*b* space was measured in order to assess the self cleaning ability of TiO_2 treated samples before and after sunlight exposure. The more value of L indicate the more color is faded by sunlight.

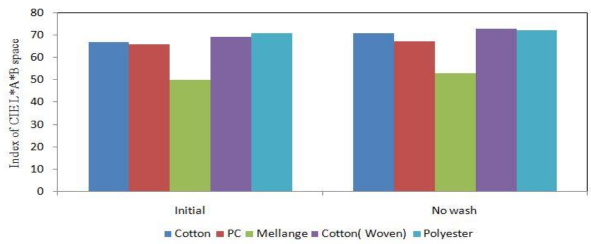

Fig.10 Spectrophotometric assessment of self-cleaning activity using TiO_2 1 gm. /100 ml

Comparing to all of the value we noticed that The Highest value of depthness was in for cotton woven fabric which was 71.74 and the lowest value is for Mellange which was 52.69 after exposing at sunlight. There for cotton woven fabric showed best result here.

3.7 Spectrophotometric assessment of self-cleaning activity

The Highest value of depthness was in for cotton woven fabric with (no wash) which is 71.53 and the lowest value is for Mellange which is 50.66 after no wash. The lowest values are even better than the Initial value. The other values are among these values.

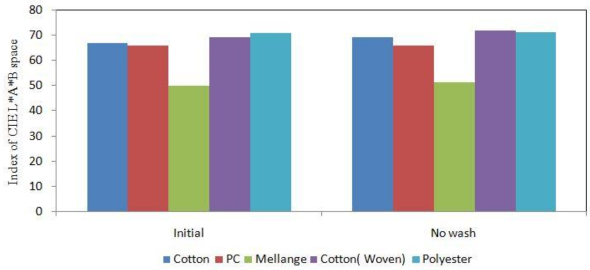

Fig.11 Spectrophotometric assessment of self-cleaning activity using TiO_2 2 gm. /100 ml

Comparing to all of the value we observed that the, Cotton based fabric gave the most efficient result. But cost was increased when doubling the concentration.

3.8 Absorbency test of the TiO_2 treated fabric

To investigate the effect of TiO_2 on the absorbency on the textile fabrics we tested these samples absorbency. We observed that at two times was there was slight change of absorbency compared with untreated samples expect for the polyester woven fabric which noticed the The Highest value of absorbency was in for cotton woven fabric which is 132.49 and the lowest value is for polyester which is 21.37 which better than its initial values. The other values are among these values.

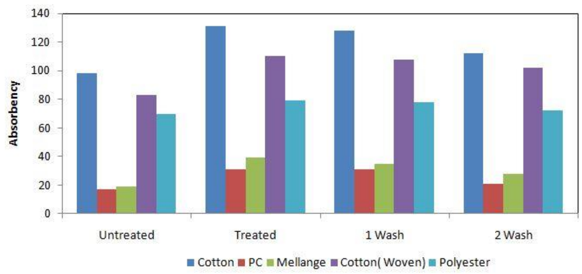

Fig.12 Absorbency of fabrics using TiO_2 1 gm. /100 ml

Comparing to all of the value we can say that the, the absorbency fabric is remarkably increased. Where we can see that cotton fabric has an absorbency more than 100% and Polyester absorbency was doubled.

3.9 Absorbency Test of the TiO_2 Treated Fabric

The Highest value of absorbency was in for cotton woven fabric which is 143.52 and the lowest value is for Polyester which is 23.74 which is better than its initial value of 15.3. The other values are among these values.

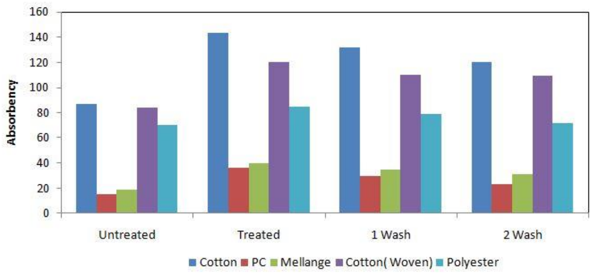

Fig.13 Absorbency of fabrics using TiO_2 2 gm. /100 ml

Comparing to all of the value we can say that the**,** the absorbency fabric is remarkably increased. Where we can see that cotton fabric has an absorbency more than 100% and Polyester absorbency is doubled. However, comparing to cost and breathability TiO_2 solution with concentration 1gm/ 100 ml is optimum.

3.10 Breathability Test of the TiO_2 Treated Sample

The Highest value of Breathability was in for Polyester woven fabric which is 2.17 and the lowest value is for PC which is 0.47. The other values are among these values.

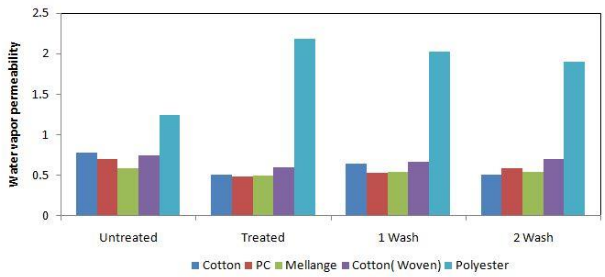

Fig.14 Water vapor permeability of fabrics using TiO_2 1 gm. /100 ml

Comparing to all of the value we can say that the breathability of the fabric is remarkably decreased. From the graph we can see that the breathability is decreased in case of all the fabric except for the fact of Polyester. After all the things the breathability of Polyester is exceptional.

3.11 Breathability Test of the Sample

The Highest value of Breathability was in for Polyester woven fabric which is 20% and the lowest value is for PC which is 0.36. The other values are among these values.

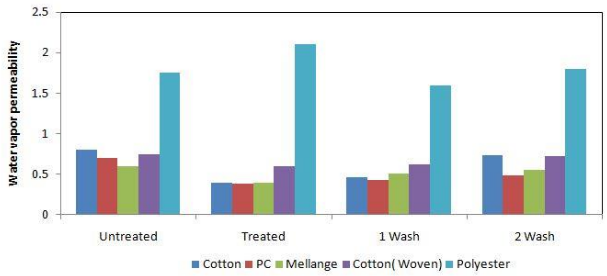

Fig.15 Water vapor permeability of fabrics using TiO_2 2 gm. /100 ml

Comparing to all of the value we can say that the breathability of the fabric is remarkably decreased. From the graph we can see that the breathability is decreased in case of all the fabric except for the fact of Polyester. After all the things the breathability of Polyester is exceptional. However compared to cost and efficiency the Optimum concentration should be around 1gm/ 100 ml solution of TiO_2.

4. Conclusion

In this experiment Photo catalytic efficiency of TiO_2 treated 100% cotton (woven), 100% cotton (knitted), PC(knitted), 5% Grey Mellange (knitted) 100% polyester (woven) were analyzed to investigate the self cleaning capability of treated fabrics and relationship between fabric structure and self cleaning efficiency of treated fabric. Based on the data available it can be said that if we want to impart self-cleaning property on Textiles we have to consider the conc. of TiO_2 which is not more than 2g/100 mL and of course only cotton based textile shows more the self-cleaning activity than others. One noticeable outcome that woven fabrics perform more actively remove stains than knitted fabric. Absorbency of TiO_2 treated woven fabric increases remarkably it can absorb water more than its weight. The hydrophobicity of polyester fabric decreases in a great scale. But the breathability decreases when TiO_2 concentration increases except coating slightly except polyester.

These samples would be treated by fluorocarbon to impart self-cleaning activity much better than TiO_2 treatment. Besides imparting self-cleaning property anti-microbial, anti-inflammatory, water absorbency also would be gained by further investigation by TiO_2 treatment.

5. References

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