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Ultraviolet Protective Finish on Cotton Using Nanotechnology

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Abstract : *Nanotechnology is the utilization of structure and energies inherent in materials at the atomistic level, at the dimension of 10^{-9}nm, to build novel textile materials with enhanced performance/functional properties. The application of Nanotechnology in the finishing of textiles has always helped to improve quality and performance of textile materials by adding new functions on textile material without compromising on its existing functions like durability, its feel and its original texture. This study focuses mainly on application of TiO2, hence application was done using different concentrations of TiO2, while concentration of Binders was kept constant. The extraordinary photocatalytic activity, non-toxicity, high availability and biocompatibility makes TiO2 nanoparticles the preferred material for this study. The two types of TiO2 nanoparticle material are present in the market, first is imported (Sigma brand) and second one is available under local brands. The Titanium Dioxide (TiO2) nanoparticle was also evaluated for size and crystallinity calculations. The present study was conducted to evaluate domestically available Titanium Dioxide from local manufacturers and was imparted on cotton fabric to evaluate its physical and functional properties through coating. The coating was applied by the Pad-Dry-Cure method. Different physical properties like tensile strength, GSM of the fabric, abrasion resistance and Fabric count were evaluated, while some functional properties like water repellency, UV protection factor and Antimicrobial were also evaluated by ISO standard tests. The UV Protection Factor was found excellent. The treated sample showed slight antimicrobial activity with higher concentration of TiO_2. Final Protective Textile Products were developed on the basis of UV protection and Anti-microbial activity.*

Keywords: *Nanotechnology, Titanium Dioxide Nanoparticle, UV Protection Finish, Acrylic Binder, Polyurethane Binder, Protective Textiles.*

1. INTRODUCTION:

The word Nano means small in size. The Nano in technology comes from the Greek word meaning "Dwarf". Nanotechnology was defined as the study of different structures whose size ranged between 1 to 100 nanometers. This is too small to even be visible to the human eye. This is equal to 100000 smaller than human hair diameter. The study shows that particles at this level show tremendous properties then their original macro size form. Dealing with this size, understanding, manipulating and controlling matter at Nano-size level so that many chemical, physical, or biological properties of the material can be improved or in better word engineered to develop the next level of advanced materials.

The history of nanotechnology was generally understood to have begun in December 1959. A physicist Richard Feynman gave a speech, "There is plenty of room at the bottom" at an American physical society meeting at the California Institute of Technology. He was the first person to identify the potential of nanotechnology. In 1974, Norio Taniguchi first used the word "nanotechnology", in regard to an ion sputter machine, to refer to "production technology to get the extra-high accuracy and ultra-fine dimensions, i.e. the preciseness and fineness on the order of one nanometer". In 1980, Eric Drexler authored the landmark book nanotechnology, "Engines of Creation". The book introduced the concept of molecular manufacturing to the public. By the 1990s, nanotechnology was advancing rapidly.

Titanium Dioxide is also known as titanium (IV) oxide or Titania. It is a naturally occurring metal oxide. The chemical formula for titanium is TiO2. The other names of titanium dioxide are Rutile, Anatase and Brookite. Titanium dioxide (TiO2) is found in the form of Anatase (mineral). The mineral is black solid; however, the pure form is colorless or white. The Anatase is always found as a small, sharply isolated crystal. It is a more commonly occurring modification of titanium dioxide. Anatase is found in two growth habits. One is most commonly occurring with simple acute double pyramids which are found in indigo-blue to black color and have a steely luster. Similar crystals but of microscopic size are widely distributed in Sedimentary Rocks, like sandstones, slates and clays and then they are separated by washing away the lighter constituents of the powdered rock. The anatase is the most stable thermodynamically surface and thus most widely exposed facets in natural and synthetic anatase.

2. LITERATURE REVIEW:

Farj A., et al, (2018), discussed the study conducted on cotton and polyamide fabric to impregnate antimicrobial activity using encapsulation of Origanun Vukgare L. essential oil into nano and micrometer sized particles. The synthesized particles were impregnated on polyamide and cotton fabric by padding for antimicrobial finish. The treated fabric was then evaluated for application on a wound dressing. The surface of textile material was then characterized by scanning electron microscopy (SEM). The polyamide fabric showed better substantivity results than cotton.

Chowdhury K.P., (2018), has studied the change in functional properties of woven and knitted cotton fabric by application of a special finish. This study mainly focused on application of chemical finishes and evaluated their impact on both the fabrics. This study is based on nine different finishes applied on cotton fabric. The first finish was an antistatic finish with siligen softener SIH which is a type of polysiloxane. Second was polyurethane with perapret additive. Next two finishes were silicon (Micro) and silicon (Macro) with SIE siligen softener. Fifth finish was polyethylene with PEP perapret additive. Sixth finish was a water repellent finish. A wrinkle free finish was applied on the seventh sample by using Fixapret ECO. A paper touch finish was done with the use of perapret VA finishing agent was the eight finish and the final sample was given a silky soft finish by perapret F-PEB. All the samples were tested for GSM, Drop absorbency time, Tensile strength test, bursting strength test, shrinkage percentage, crease recovery angle and spray rating test. The effect of the finishes was observed on both woven and knitted fabrics. The results showed that there were changes in the chemical properties of the cotton fabric after the finishes were imparted on the material. No noticeable changes were observed on the physical properties of finished cotton fabrics.

Mahmud R., et al, (2017), stated that the aesthetic properties and functional properties of textile products were gaining demand. To fulfill customer satisfaction new technology was developed in different areas of technical textiles. Various types of high-performance textiles were produced by various methods of coating or manufacturing techniques. The Nano-sized (10-9m) particles were applied on finished clothing. These nanoengineered textiles cover water repellent, wrinkle resistance, protective textiles, hygiene textiles, antiballistic or bullet proof. Nanotechnology improves the fiber and fabric for humans without affecting its inherent properties like comfort. This study highlights the applications of nanotechnology and enhances the functional properties in textile applications.

Das S C., (2014), observed that Nanotechnology was booming around in almost all Fields let it be Hollywood or major Universities around the globe. It was one of the latest innovations that was shaping our future lifestyle. Nanotechnology is a much more attractive field all because of the properties it inherits wherever it is applied. Textile is the major field of its application. The researcher concluded that nanotechnology can be applied in textiles to improve its functional properties. [4]

Kesavan A., et al (2014), Nanotechnology was believed to be the second industrial revolution that benefited human life in every way. It was clearly seen that numerous human and environmental benefits have been achieved globally by Nanotechnology. Many research works were done on Nanomaterials. Its success can be measured by this research going on and interest growing in this field. This is only because of the abundant properties they have at Nanoscale.

3. MATERIALS:

The Fabric used for this research is 100% Bleached woven Cotton fabric sourced from Crawford market.

1. Chemicals used are
    a. TiO_2 Nano-particle in anatase powder form.
    b. Acrylic water-based binder.
    c. Polyurethane (PU) water-based binder.
    d. Distilled Water.

2. Equipment and Machinery used for application (coating)
   a. Weighing Machine
   b. High Speed Dispenser
   c. Pad-Dry-Cure Machine

4. METHOD:

The Titanium Dioxide (TiO2) was applied on the 100% Cotton fabric using Pad-Dry-Cure method, using two binders i.e. Acrylic Base binder and Polyurethane Base Binder, at different concentrations of TiO2, keeping temperature of curing constant at 120ºC. The treated samples were then tested for UV Protection Factor, Tensile Strength and GSM of the fabric .The tested samples were then compared with the original fabric for better understanding of application and its effects on the fabric treated. The sample that gave the best result was then evaluated for Durability against 5 and 10 washes.

Table 1:Recipe for application of coating with Acrylic Binder.

Sample Name	Concentration (%) gpl.	Titanium Dioxide (TiO_2)	Acrylic binder	Water
AB 1	1%	0.25 gm	15 ml	235 ml
AB 2	3%	0.75 gm	15 ml	235 ml
AB 3	5%	1.25 gm	15 ml	235 ml

1.2 Table 2: Recipe for application with Polyurethane Binder (PU)

Sample	Concentration % gpl.	Titanium dioxide (TiO_2)	Polyurethane (PU) Binder	Distilled Water
PU 1	1%	0.25 gm	15 ml	235 ml
PU 2	3%	0.75 gm	15 ml	235 ml
PU 3	5%	1.25 gm	15 ml	235 ml
PU 4	10%		15 ml	235 ml

The curing temperature was kept 120 C for 2 minutes for all the samples.

Preparation of the Recipe

1. First the weight of the TiO2 was taken by a weighing machine as per the recipe shown in the table.
2. The binder was measured in the beaker as per above recipe.
3. T/he TiO2 weighed was then mixed with binder and distilled water was added which is constant in all recipes (235 ml).
4. The solution was then mixed using an electrical mixer having 10000 rpm (rotations per minutes) for 20 mins.

Procedure for application

1. The sample of 30 X 40 inches in size was dipped completely in the solution.
2. Then the dipped sample was passed in the Pad-dry Cure Machine with pressure _.
3. The padded sample was then passed through a curing machine at 120º C temperature for 2 minutes.
4. This procedure was done for each sample and for all three concentrations.

The preparation of recipe and procedure was same for both the binders.

Figure1. Weighing Machine

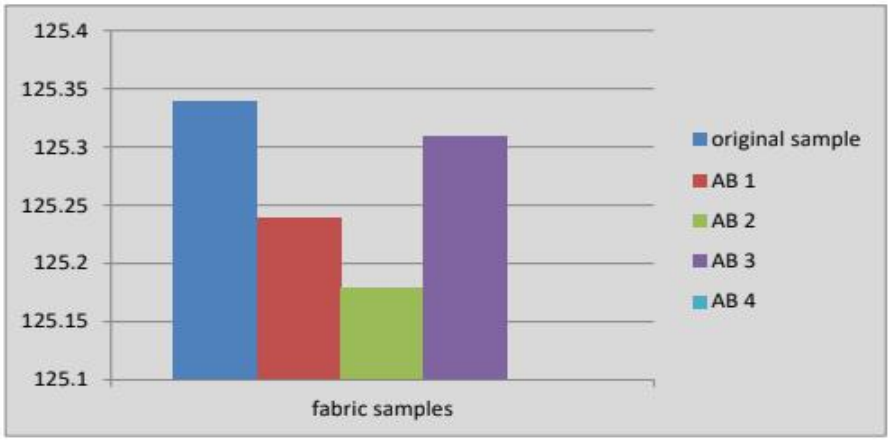
Figure 2. High speed dispenser

Figure 3. Application process using Pad-Dry-Cure method

5. RESULTS:

Effect on G.S.M of the Fabric

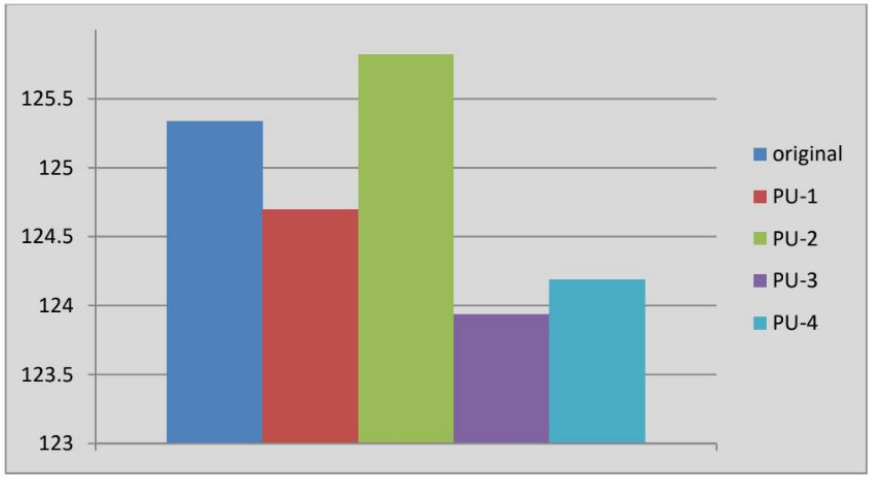
Effect TiO2 with Acrylic binder on the G.S.M of the fabric



From above, the sample treated with 5% concentration shows higher GSM while sample treated with 3% concentration

showed lowest GSM.

Effect TiO2 with PU binder on the G.S.M of the fabric



Above data shows a great difference between samples. The sample treated with 3% concentration showed high G.S.M, while the sample treated with 5% concentration showed lowest G.S.M.

Effect on Tensile strength

Table 3: Effect TiO2 with Acrylic binder on the tensile strength (warp) of the fabric

Sample Code	Original Sample	AB-1	AB-2	AB-3
Tensile Strength warp Kgf/50mm	48.8	50.7	49.1	50.3

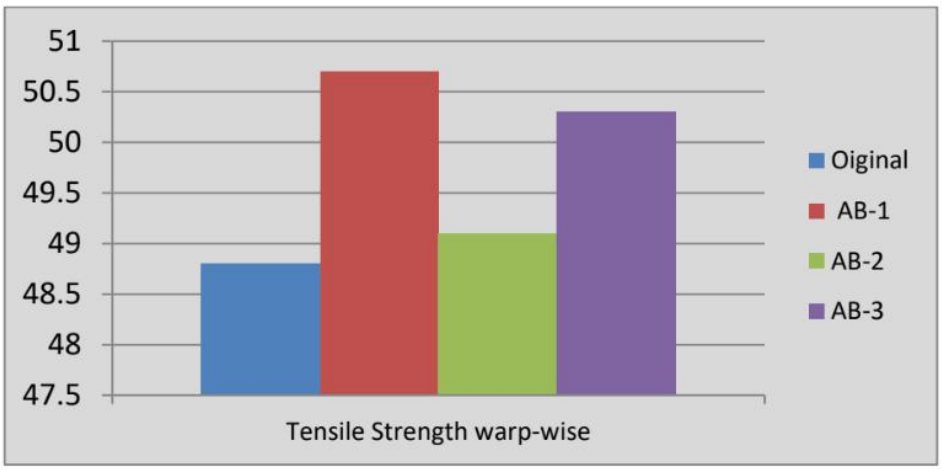
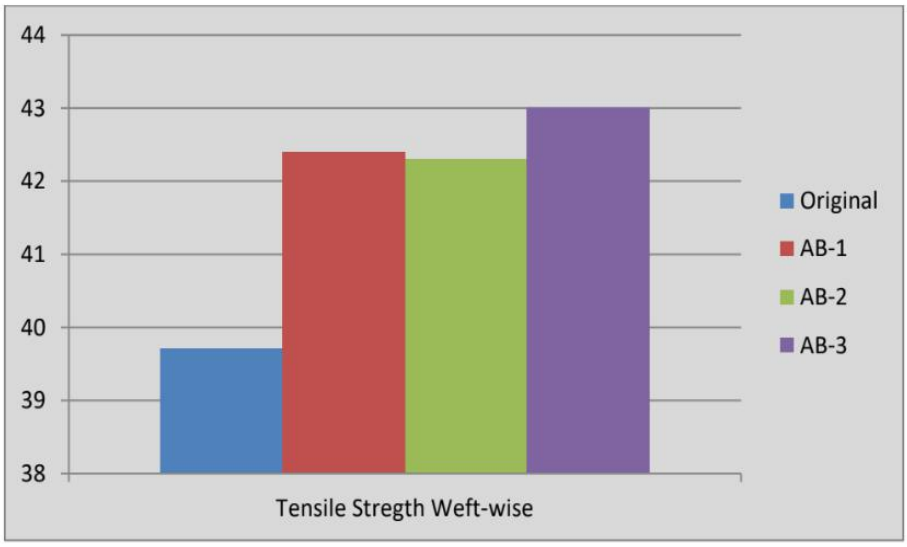


Table 4: Effect TiO2 with Acrylic binder on the tensile strength (weft) of the fabric

Sample Code	Original Sample	AB-1	AB-2	AB-3
Tensile Strength warp Kgf/50mm	39.7	42.4	42.3	43



From above table and figures, the sample treated with 1% concentration have given better tensile strength warp wise and 5% concentration weft wise.

Table 5: Effect TiO2 with PU binder on the tensile strength (warp) of the fabric

Sample Code	Original Sample	PU-1	PU-2	PU-3	PU-4
Tensile Strength warp Kgf/50mm	48.8	45.02	45.73	47.42	32.64

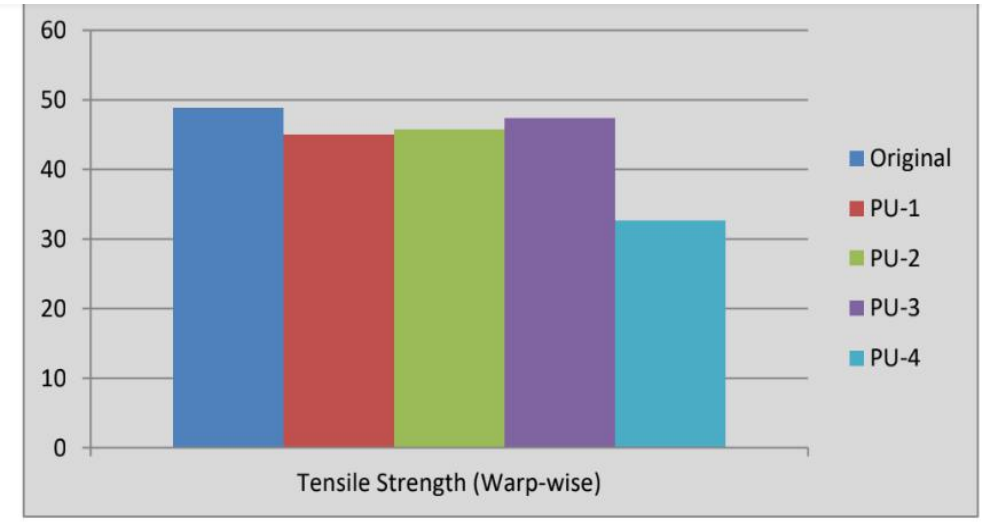
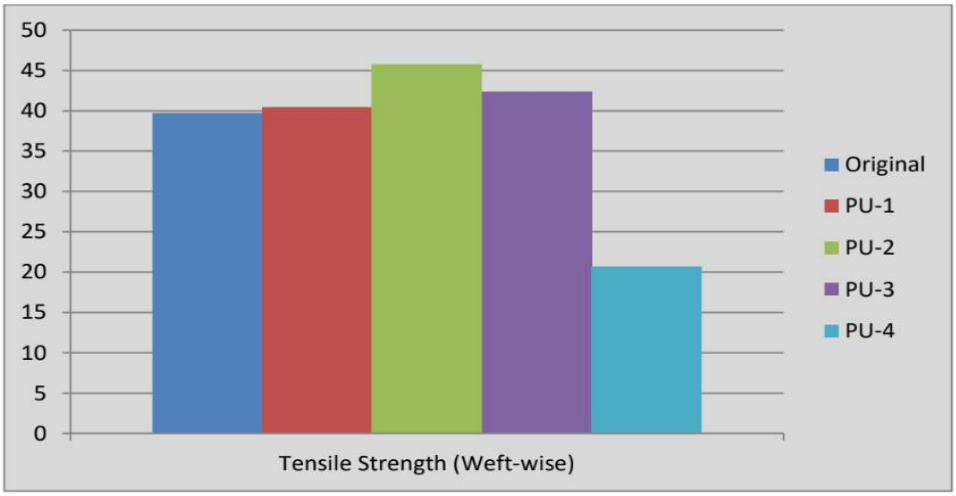


Table 6: Effect TiO2 with PU binder on the tensile strength (weft) of the fabric

Sample Code	Original Sample	PU-1	PU-2	PU-3	PU-4
Tensile Strength warp Kgf/50mm	39.7	40.41	45.72	42.37	20.64



From above tables and figures, the sample treated with PU binder showed decreased strength warp wise and 3% concentration showed increased strength weft wise.

UV Protection Factor

Table 7: Effect of Tio2 with Acrylic binder on UV factor

Test Parameter	Original Sample	AB-1	AB-2	AB-3
UV Protection Factor	25.37	27.34	52.80	40.16
UV-A Transmittance	2.84	2.73	1.61	2.11
Uv-B Transmittance	3.69	3.47	1.90	2.33
UV-A Blocking	97.16	97.27	98.39	97.89
UV-B Blocking	96.31	96.53	98.10	96.67
UPF Rating	25 (Very Good)	25 (Very Good)	30 (Very Good)	35 (Very Good)

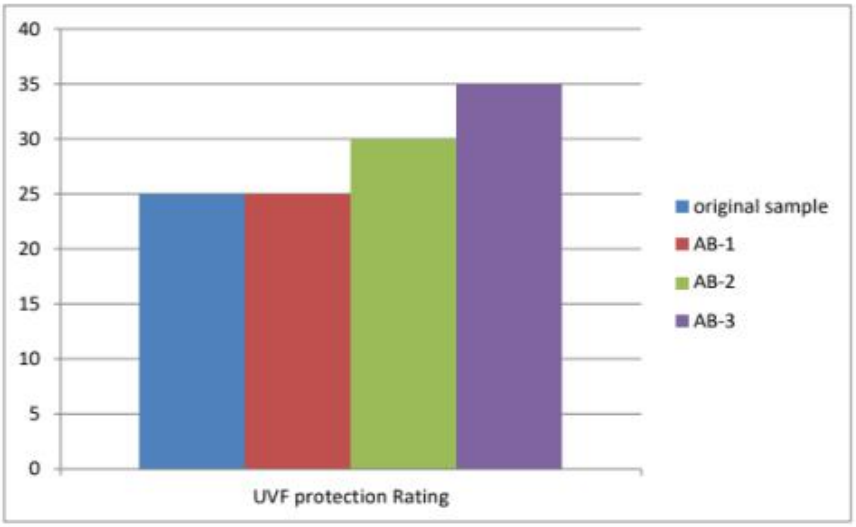
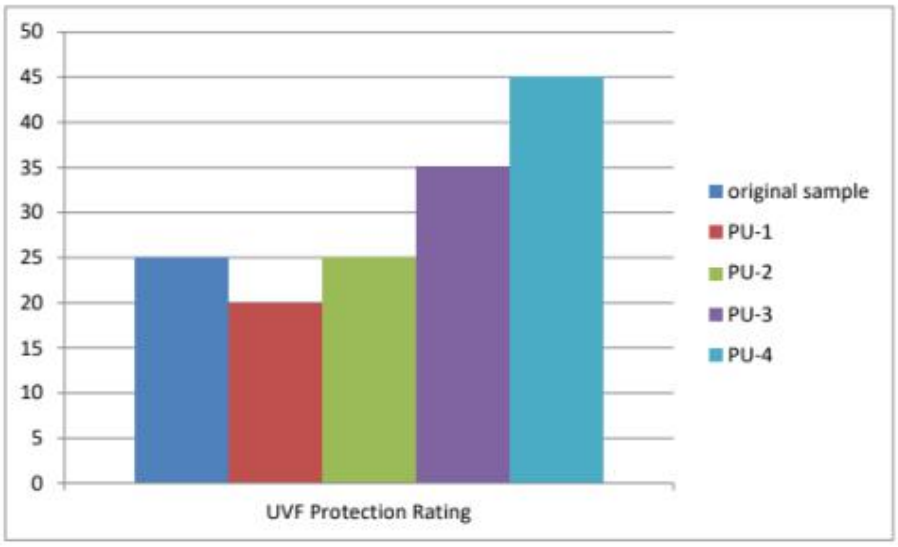


Table 8: Effect of Tio2 with PU binder on UV factor

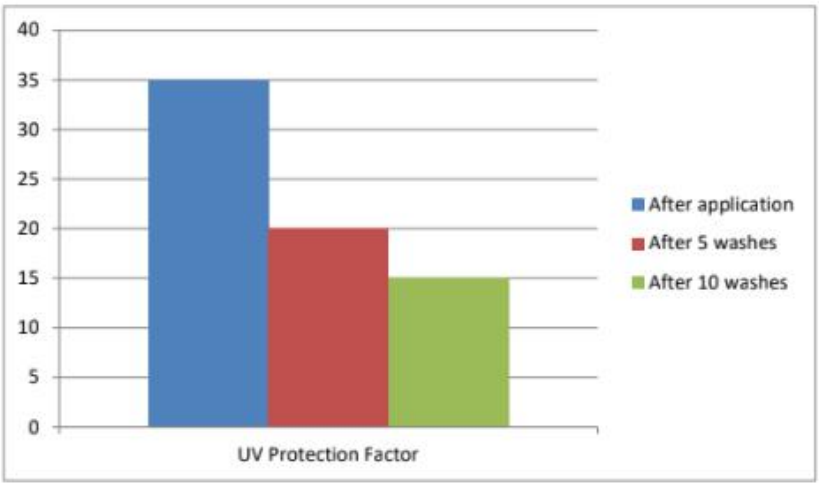
Test Parameter	Original Sample	PU-1	PU-2	PU-3	PU-4
UV Protection Factor	25.37	26.56	33.28	45.16	66.63
UV-A Transmittance	2.84	2.89	2.44	1.98	1.29
Uv-B Transmittance	3.69	3.53	2.81	2.16	1.48
UV-A Blocking	97.16	97.11	97.56	98.02	98.71
UV-B Blocking	96.31	96.47	97.19	97.84	98.52
UPF Rating	25 (Very Good)	20 (Very Good)	25 (Very Good)	35 (Very Good)	45 (Excellent)



From the above table and figures, the sample treated with 5% concentration of TiO2 with Acrylic binder gives best UV protection, while sample treated with 5% TiO2 using PU binder gives best UV protection.

Table 9: Durability/Washing Fastness against Uv Protection

Test Parameter	After finish	After 5 washes	After 10 washes
UV Protection Factor	45.16	27.15	23.27
UV-A Transmittance	1.98	3.33	3.70
Uv-B Transmittance	2.16	3.48	4.07
UV-A Blocking	98.02	96.67	96.3
UV-B Blocking	97.84	96.52	95.93
UPF Rating	35 (Very Good)	20 (Good)	15 (Good)



From the above data it was found that UV protection finish was decreased with the washes, but still UVF was found good.

6. DISCUSSION:

As latest technology develops it becomes costly for the general public to afford so this study was done by using locally available Titanium Dioxide (TiO_2). From the present study it was concluded that domestically available Titanium Dioxide showed great variation in size. The crystallinity % of Titanium Dioxide was less than amorphous % so it can be stated that finish applied using this nanoparticle cannot be used for water repellency finish. When GSM of the fabric was compared with coated sample with different concentration, it was found that GSM of cotton fabric decreased with an increase in concentration on TiO_2 .Tensile strength was improved weft-wise when treated with Acrylic Binder, but when compared to polyurethane Binder it doesn't affect warp-wise tensile strength and in weft-wise same behavior was observed. Least tensile strength was observed with 10% concentration with Polyurethane Binder. Abrasion resistance was good for all samples.The UV protection Factor was evaluated for both and was found significantly good. The durability of UV Protection was also observed satisfactory for 5 and 10 washes.

As global warming is increasing day by day there is a strong need for changes in textile processing to be adopted. By using Nanotechnology many processes can be shortened and water which is wasted in heavy laundering can be saved. This is possible with finish applied through Nanomaterials. For example, Australia is one of the top countries which have highest rates of cancer due to great UV exposure. So, there is a strong need to develop UV Protected Textiles.

7. CONCLUSION:

From the study following conclusion were made.The size of nanoparticles affects the property it gives to the textile material, so difference in size, may result in different behavior when applied to textile material. This study was done with domestically available Titanium Dioxide was used instead of costly imported one, to make it economical. From the above study it can be concluded that samples treated with 5% TiO_2 showed best results with respect to tensile strength. Antimicrobial activity was observed with higher concentration of TiO_2 coating with polyurethane Binder. The durability of UV Protection finish was good even after 10 washes.

8. RECOMMENDATIONS:

The study is limited to application of Titanium Dioxide (TiO_2) Nanoparticles only. Only Cotton fabric is used for the study. further study can be conducted for other fabrics as well, depending upon properties required.

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