Synthesis And Application Of Nano Copper Oxide For Antimicrobial Property

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Abstract
With the growing demand for comfortable, clean and hygienic textile goods, an urgent need for production of antimicrobial textile goods has arisen. In this study, synthesis of nano copper oxide has been done by direct precipitation method and its characterisation done to determine the crystallinity and particle size. It is applied on textile cotton substrate and tested for its antimicrobial activity. Improvement in durability of applied agent with the use of binder was attempted and results discussed. Finishing treatment is one of the most important steps but costly, and hence attempt has been made to combine wrinkle recovery and antimicrobial finish by the use of cross linking agent and nano copper oxide simultaneously.

Keywords
Antimicrobial, Nanotechnology, Nano copper oxide, Combined finishing

1. Introduction

1.1 Nanotechnology

World wide there is increase in demands for improved or even new properties of textiles, especially technical textile as high performance products. Nano-science and nanotechnology combined, have revitalized material science. This has led to the development and evolution of a new range of improved materials including polymers and textiles through nanostructuring and engineering. Nanotechnology is an emerging interdisciplinary area that is expected to have wide ranging implications in all fields of science and technology such as material science, mechanics, electronics, optics, medicine, energy and aerospace, plastics and textiles.
There has been a clear shift to nanomaterials as a new tool to improve properties and gain multi functionalities. As indicated in an overview on impact of nanotechnology on textiles, organized nano structures seem to have immense potential to revolutionize the textile industry as exhibited by either fibers, nanocoatings, nanofinishing, nanofibers and nanocomposites with new functionality such as self cleaning surfaces, conducting textiles, antimicrobial properties, controlled hydrophilicity or hydrophobicity, protection against fire, UV radiation etc. without affecting the bulk properties of fibers and fabrics [1].

1.2. Antimicrobial finish

Due to the growing demand for comfortable, clean and hygienic textile goods, an urgent need for production of antimicrobial textile goods has arisen. With the advent of new technologies, the growing needs of consumers in terms of health and hygiene can be fulfilled without compromising issues related to safety, human health and the environment. [2]

In textile substrates, a number of undesirable effects are caused by microbes. It causes rapid rotting of unprotected natural fibres. An uncontrolled growth of microbes on textile surface leads to consequent increase in bio burden levels. Growth of microbes on textile further triggers the onset of degradation phenomenon causing objectionable microbial stains and discolouration of textile materials. These microbes further posses potential health risk and discomfort due to the unpleasant odors, incidence of skin infections and allergies. [3]

The term 'antimicrobial' comprises a series of particular agents that act against specific forms of microrganism, such as bactericide (antibacterial), fungicide (antifungal), insect proofers, moth proofers, herbicides, algaecides, rot proofers and anti-dust mite products. Several metallic and organometallics salts, phenolic and anilide derivatives and quaternary amine salts can inhibit the growth of bacteria and fungi on fibres. Though the use of antimicrobials have been known for decades, it is only in the recent couple of years that several attempts have been made on finishing textiles with antimicrobial compounds. [4]

Antimicrobial agents inhibit or kill the microorganisms by several ways. The manner in which antimicrobial agents inhibit or kill can be attributed to cell wall damage or inhibition of cell wall synthesis, alteration of cytoplasmic membrane permeability, alteration of the physical or chemical site of proteins and nucleic acids, inhibition of enzyme action and inhibition of protein or nucleic acid synthesis. Nano particles have an extremely large relative surface area, thus increasing their contact with bacteria or fungi and vastly improving their bactericidal and fungicidal effectiveness. [5]

1.3 Metals & their Salts

Most of the heavy metals, either alone or in form of compounds exert a detrimental effect upon microorganisms. The most effective are silver, copper [6] and zinc. Heavy metals and their compounds act as antimicrobial agent by combining with cellular proteins and inactivating them. High concentrations of salts of heavy metals coagulate cytoplasmic proteins resulting in damage or death of the cell.

Copper and its alloys are natural antimicrobial materials. Ancient civilizations exploited the antimicrobial properties of copper long before the concept of microbes became understood in the nineteenth century [7]. In addition to several copper medicinal preparations, it was also observed centuries ago that water transported in copper vessels was of better quality than water transported in other materials. Recently, antibacterial action of copper on microbe has been a subject of intensive research.

2. Materials and methods

2.1 Materials

2.1.1 Substrate

100 % Cotton fabrics obtained from Piyush Syndicate, Mumbai. The fabric specifications were Plain (1/1) weave, GSM 108 gm/m^2, PPI/EPI 130/68, Warp Count 36s, Weft Count 30s.

2.1.2 Chemicals

Sodium Hydroxide pellets LR, Copper Sulfate AR were supplied by Ami Chemicals of SD Fine, Mumbai and Ethanol (absolute alcohol) was supplied by Changshu Yangyuan Chemical, China.

2.1.3 Media for Antimicrobial Testing

The chemicals Nutrient Broth, Nutrient Agar, Agar Agar Type 1 were supplied by HIMEDIA, and Sodium Chloride of SD Fine Supplied by Ami Chemicals, Mumbai. Bacteria's used were Staphylococcus Aureus (NCTC 3750 grade) and Escherichia Coli (AATCC-10148 grade).

2.2 Experimental Methods

2.2.1 Synthesis of Nano Copper Oxide by Direct Precipitation Method

0.2 mol L^{-1} Anhydrous Copper Sulfate solution is taken in three neck flask which is placed on magnetic stirrer having heating device. Temperature is set at 50^0C. The solution is stirred vigorously and certain amount of 0.6 mol.L^{-1} NaOH added dropwise in three neck flask within half an hour followed by ageing for 3 hrs in order to react fully. Thorough washing is done with distilled water and then with ethanol. The product is then placed in oven at 80^0C for 4 hr. The obtained $Cu(OH)_2$ is grinded and calcined in muffle furnace at 400^0C for 2 hr to obtain nano-CuO.

2.3 Methods of Application

2.3.1 Synthesized nano particles are applied by pad dry cure technique. Required amount of nano particles are taken and pasted with distilled water then extra water added to make fixed concentration like (0.05, 0.1, 0.2 gpl). The prepared solution is kept in ultrasonicator for 15 min at room temperature to remove its aggregation. The fabric is then dipped in the solution for 1 min and then padded with each concentration on vertical padding mangle. Pickup was kept adjusted at 80%, dried at 85^{0}C for 3 min and then cured at 120^{0}C for 2 min on stenter.

2.3.2 Synthesized nano particles are applied by pad dry cure technique along with 1% acrylic binder with above concentration. The solution is mixed using high speed stirrer, then acrylic binder is added slowly in it. The fabric is dipped in solution for 1 min and then padded at 80% expression with each concentration on vertical padding mangle, dried at 85^{0}C for 3 min and cured at 140^{0}C for 2 min on stenter.

2.3.3 Synthesized nano particles are applied by padding then dried at 85^{0}C for 3 min with all three concentrations. Then the dried sample is again padded with solution containing 70 gpl DMDHEU, 20 gpl non-ionic softener and 9 gpl $MgCl_2$, Dried at 80^{0}C for 2 min and cured at 150^{0}C for 2 minute. The finishing treatment was done on verticle padding mangle, using pick-up 80%, drying at 85^{o}C for 3mins and curing at 120^{o}C for 2mins.

2.3.4. To check the durability of the nanomaterial on cotton fabric the next step was to carry out washing of the fabric with standard AATCC detergent using the Test Method 61-2006, Test No. 1A where at a temp. 40^{0}C, total liquor volume 200 ml, 0.37% AATCC detergent and 10 Steel balls, treatment is done for 45 min and the antimicrobial testing done after 5, 10 and 15 washes.

2.4 Characterization

2.4.1 X-Ray diffraction (XRD)

Wide angle XRD patterns were obtained using Miniflex, Rigaku, Japan with Cu Kα beam having wavelength (X) = 1.54 Å used as the radiation source and Ni-filter. The diffractometer was operated at 30KV and 15mA using a scanning step of 2 in two theta and a dwell time of 1 second used.

2.4.2 Transmission Electron Microscopy (TEM)

Transmission electron Microscopy (TEM) is used to characterize the nanoparticles shape, size and crystallinity by using TEM PHILIPS, Model: CM200S".

2.4.3 Scanning Electron Microscopic (SEM)

Surface morphology is characterized using SEM JEOL JSM 6380LA, JEOL ltd. Japan. Scanning electron microscope is used to characterize the surface morphology showing nanoparticles bound to the substrate.

2.4.4 Particle Size Analyzer

Particle Size of colloidal solution is measured by ZETASIZER MALVERN made in UK.

2.5 Finished Fabric Property Analysis

2.5.1 Antimicrobial testing

The antibacterial activity of the treated samples is carried out by standard procedure using AATCC 100-2004 method. Bacterial counts are reported as the number of bacteria per sample. Percent reduction of bacteria by the treated specimen is calculated by the following formula:

$100 (B – A)/B = R$

Where

R = % reduction in bacteria

A = the number of bacteria recovered from the inoculated treated test specimen swatches in the jar incubated over the desired contact period (24hrs)

B = the number of bacteria recovered from the inoculated untreated test specimen swatches in the jar immediately after inoculation (at"0" contact time)

2.5.2 Tensile strength and Elongation at break

The fabric strength is determined according to the ASTM D 5035(1995), standard test method for breaking strength and elongation of Textile Fabrics on Tinius Olsen H5KS universal testing machine (UTM) tensile strength testing instrument. This test method covers raveled strip and cut strip test procedures for determining the breaking force and elongation of most textile fabrics.

2.5.3 Stiffness testing

The fabric stiffness is evaluated by ASTM D 1388(1996), Standard Test Method for Stiffness of fabrics. This test method covers the measurement of stiffness properties of fabrics such as bending length which is measured by using Cantilever Test, employing the principle of cantilever bending of the fabric under its own mass.

2.5.4. Crease Recovery Angle

Crease recovery angle was determined by ISO 2313(1972) on Shirley Crease recover angle instrument. Creases in textile fabrics diminish at varying rates on the removal of the creasing forces. The magnitude of the crease recovery angle is an indication of the ability of a fabric to recover from accidental creasing.

3. Results and Discussion

The synthesized nano copper oxide particles were characterized with the help of X-ray diffraction pattern which is shown in **Figure I** to determine the purity and crystallinty of the product. No peaks due to impurity were observed, which suggests that high purity CuO was obtained. In addition, the peak was widened implying that the particle size is very small. The peaks assigned to diffractions from various planes correspond to hexagonal close packed structure of copper oxide. The broadening of peaks was observed mainly due to the Nano size effect. When compared with standard diffraction it was found to be matching. Line of monoclinic CuO is uniform indicating good crystalline product.

Figure I: XRD peaks of synthesized nano CuO

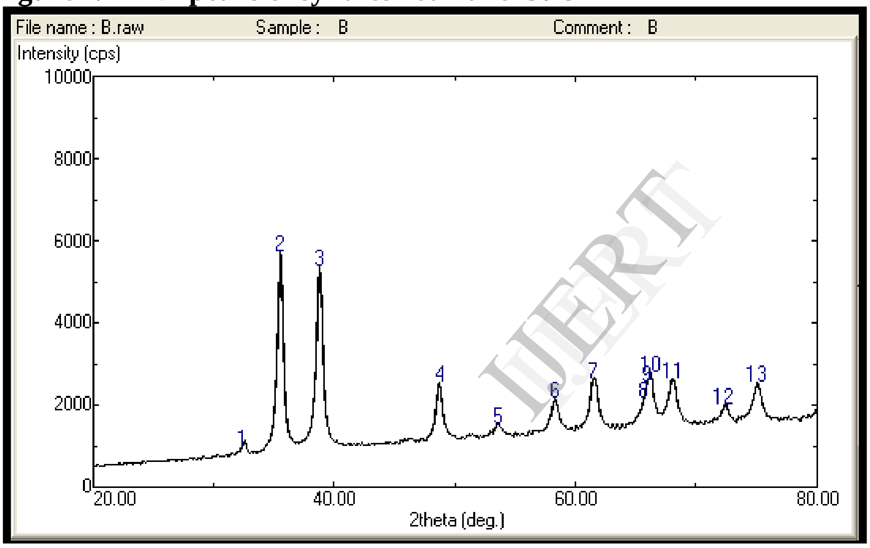
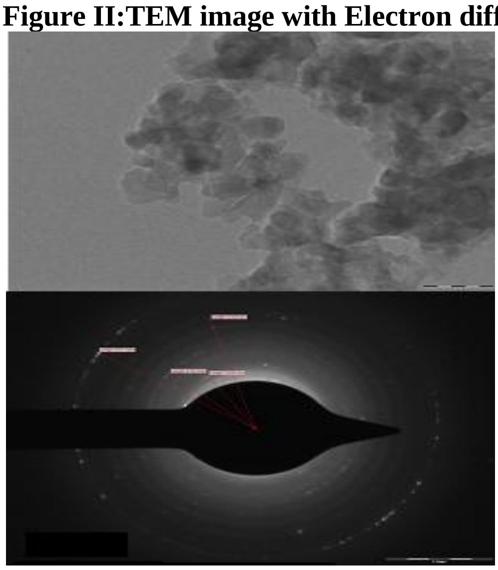


Figure II:TEM image with Electron diffraction(ED) pattern of Nano CuO



The crystal size, micrograph and electron diffraction(ED) pattern determined from TEM are shown in **Figure II.** TEM images show regular and spherical like morphology. The CuO powder appears aggregated with the particle size range of 40-60 nm. The electron diffraction of Nano CuO is clearly visible as three diffraction rings, the brightest ring being closest to the centre.

Having synthesized nano copper oxide, it was applied on cotton fabric and was used to evaluate the performance of the nano particles to be used as antimicrobial agent.

Table I. Action of Nano CuO on Cotton fabric and its antimicrobial activity against *S. Aureus*

Conc. of nano CuO (gpl)	No. of colonies after		% Reduction of number of colonies
	0 hr	24 hr	
Untreated	790	1360	0
0.05	425	237	70
0.1	300	119	85
0.2	112	39	95
0.25	42	16	98
0.3	21	8	99

The results with respect to Gram positive and Gram negative bacteria namely *Staphylococcus aureus* and *Escherichia coli* are given in **Table I and II**. From the tables it can be said that even at very low concentration like 0.05gpl of nano copper oxide, the fabric showed antimicrobial property against both type of bacteria. In both cases it is evident that as the concentration of the nanomaterial increases the % reduction of bacteria also increases. In other words, higher is the concentration of the nanomaterial on the fabric, higher is the possibility of its diffusion in the nutrient and thus more is its resistance to the growth of microorganisms. The control sample i.e. untreated sample did not show any reduction and on the contrary has shown increase in the number of bacterial colonies which clearly indicates that the fabric only acts as a vehicle or carrier for the nanomaterial and does not interfere in any ways in the reduction of microbial growth. The range of % reduction for Gram positive bacteria is 70-99% while for gram negative bacteria is 60-94%. Practically a 95% reduction in colonies was observed for both bacteria at a concentration of 0.2 gpl of nano copper oxide.

Table II. Action of Nano CuO on Cotton fabric and its antimicrobial activity against *E. Coli*

Conc. of Nano CuO (gpl)	No. of Colonies after		% Reduction in number of Colonies
	0 hr	24 hr	
Untreated	735	1300	0.00
0.05	500	228	69.05
0.1	312	137	81.36
0.2	98	46	93.75

The results of the Durability test in terms of washing of the fabric with standard AATCC detergent using the Test Method 61-2006, and the antimicrobial testing after 5, 10 and 15 washes are shown in **Figure III and IV**. The range of % reduction of number of colonies for Gram positive bacteria i.e. *S Aureus* before wash was 70-95% which reduced to 65-90% after 5 washes, 54-80% after 10 washes and it further reduced to 21-45% after 15 washes. This was because with every wash some amount of nanomaterial got removed from the fabric and as the number of nanoparticles reduced, the number of particles to kill the microorganisms reduced which was observed as a decrease in the % reduction in the number of bacterial colonies. A very similar trend was observed in case of the Gram negative bacteria i.e. *E coli* where the decrease in the reduction in bacterial growth was in the range of, before wash 70-94% which decreased to 60-87% after 5 washes, 50-73% after 10 washes and it went down upto 33-48% after 15 washes.

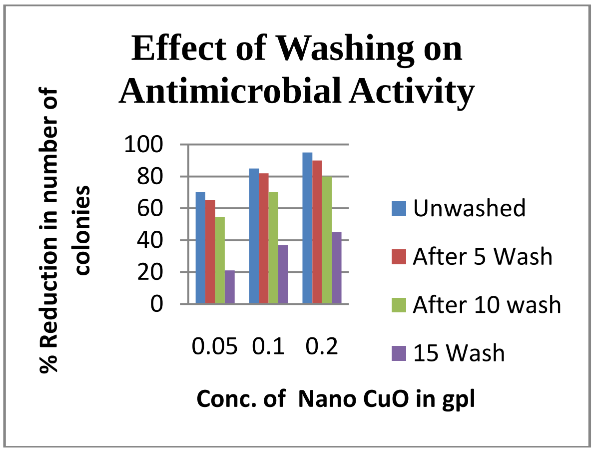


Figure III: Effect of Washing on antimicrobial activity of Nano CuO treated Cotton fabric against *S. Aureus*

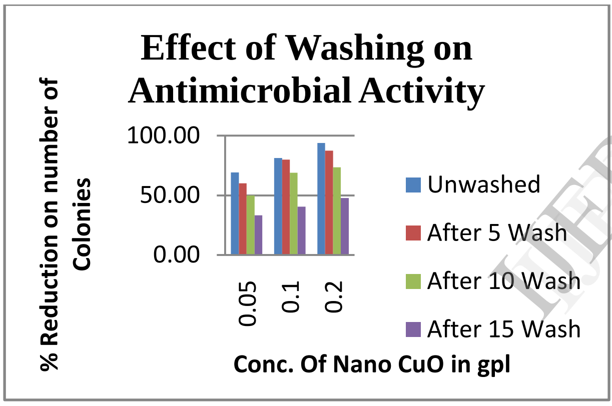


Figure IV: Effect of Washing on antimicrobial activity of Nano CuO treated Cotton fabric against *E. Coli*

To increase the durability of the nano copper oxide particles on the fabric it was applied along with an acrylic binder and the antimicrobial activity of the fabric tested. The results of the antimicrobial testing against Gram positive and Gram negative bacteria are shown in **Tables III and IV**. The value of reduction in number of colonies against both the bacteria remained the same as was without the addition of the binder, which shows that the binder does not interfere with the antimicrobial activity of the nanomaterial.

Table III: Antimicrobial activity of Nano CuO and 1% Acrylic Binder on Cotton fabric against *S. Aureus*

Conc. of Nano CuO(gpl) + 1% Acrylic Binder	No. of Colonies after		% Reduction in number of Colonies
	0 hr	24 hr	
Untreated #	790	1364	0
0.05	713	221	72
0.1	356	119	85
0.2	103	40	95

#- Indicates Fabric is treated with 1% Acrylic Binder only

Table IV: Antimicrobial activity of Nano CuO and 1% Acrylic Binder on Cotton fabric against *E. Coli*

Conc. of Nano CuO (gpl) + 1% Acrylic Binder	No. of Colonies after		% Reduction in number of Colonies
	0 hr	24 hr	
Untreated #	812	1354	Nil
0.05	612	240	70.45
0.1	312	162	80.00
0.2	102	57	93.02

#- Indicates Fabric is treated with 1% Acrylic Binder only

The durability testing of this binder and nano copper oxide treated fabrics is also carried out at 5, 10 and 15 washes against both the bacteria. The results of the tests are shown in **Figure V and VI**. As seen in **Figure V**, there is not much decrease in antimicrobial activity (% reduction in number of bacterial colonies) against the gram positive bacteria up to 10 washes as the range of antibacterial activity 72-95% of unwashed fabric reduces to only 68-93% after 10 washes. These results clearly indicate that the acrylic binder film formed on the fabric entraps the nanoparticles within it or between the cotton fabric and the binder film and hence the durability increases. As compared to the fabric not treated with the binder, the binder treated fabric shows an activity of 81% after 15 washes whereas the fabric without binder was showing an activity of only 45%.

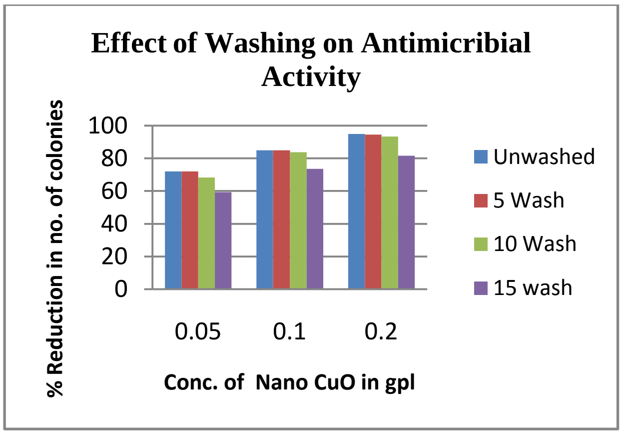


Figure V: Effect of Washing on antimicrobial activity of Nano CuO and 1% Acrylic Binder treated Cotton fabric against *S. Aureus*

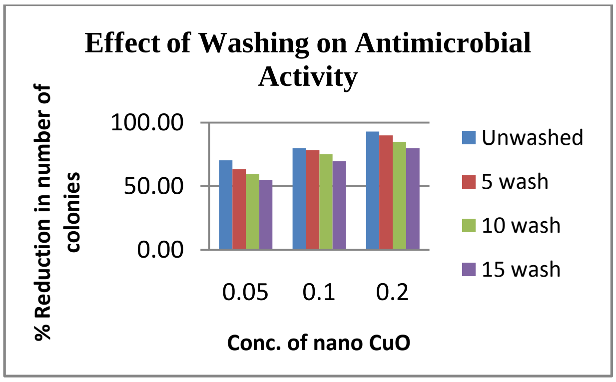


Figure VI: Effect of Washing on antimicrobial activity of Nano CuO and 1% Acrylic Binder treated Cotton fabric against *E. Coli*

Finishing treatment is nowadays one of the most important steps but costly and hence attempts to combine different finishing treatments have been attempted with a combination of DMDHEU and nano copper oxide to impart wrinkle resistance and antimicrobial activity together. The untreated sample taken here is the sample treated only with DMDHEU (without nanoparticle). The results against gram positive bacteria and gram negative bacteria are shown in **Table V and VI.** The % reduction in number of colonies are in the range 85-99% for *S Aureus* and 82-98% for *E coli*. The untreated fabric shows a reduction in the number of colonies of about 50%. When the results of the fabrics treated with nano copper oxide along with DMDHEU are compared with the ones not treated along with DMDHEU it can be seen that there is an appreciable increase in the antimicrobial activity which may be due to the synergistic effect caused by DMDHEU for antimicrobial activity.

Table V: Antimicrobial activity of Nano CuO and 70 gpl DMDHEU on Cotton fabric against *S. Aureus*

Conc. of Nano CuO (gpl)+ 60 gpl DMDHEU	No. of Colonies after		% Reduction in number of Colonies
	0 hr	24 hr	
Untreated *	880	440	50
0.05	245	130	85.31
0.1	130	47	94.62
0.2	100	9	99

* - Indicates fabric is treated with DMDHEU only

Table VI: Antimicrobial activity of Nano CuO and 70 gpl DMDHEU on Cotton fabric against *E.Coli*

Conc. of Nano CuO (gpl)+ 60 gpl DMDHEU	No. of Colonies after		% Reduction in number of Colonies
	0 hr	24 hr	
Untreated *	520	260	50
0.05	330	94	82
0.1	157	52	90
0.2	45	10	98

* - Indicates fabric is treated with DMDHEU only

The durability of the samples treated with nano copper oxide particles along with DMDHEU was determined at 5, 10 and 15 washes and the results of antimicrobial activity are shown in **Figure VII and VIII**. There is not much decrease in antimicrobial activity against the gram positive bacteria up to 15 washes as the range of antibacterial activity 85-99% of unwashed fabric reduces to only 75-91% after 15 washes. These results indicate that the particles probably gets trapped in the cross linked macromolecular chains of cellulose due to DMDHEU and hence the durability increases. As compared to the fabric not treated with DMDHEU, the DMDHEU treated fabric shows an activity of 91% after 15 washes whereas the fabric without DMDHEU showed an activity of only 45%. Hence the fabric can be easily called antimicrobial up to 15 washes with the help of DMDHEU.

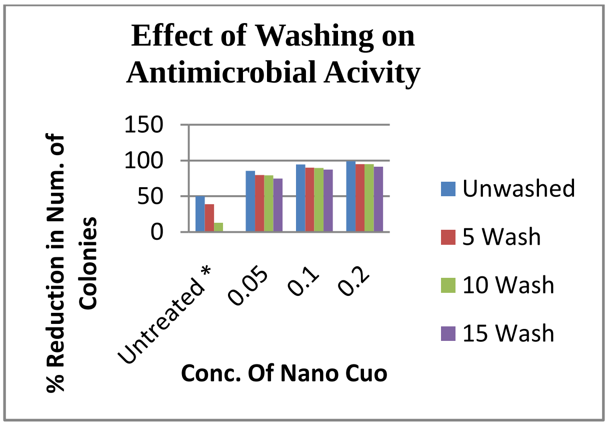


Figure VII: Effect of Washing on antimicrobial activity of Nano CuO and 70 gpl DMDHEU treated Cotton fabric against *S.Aureus*

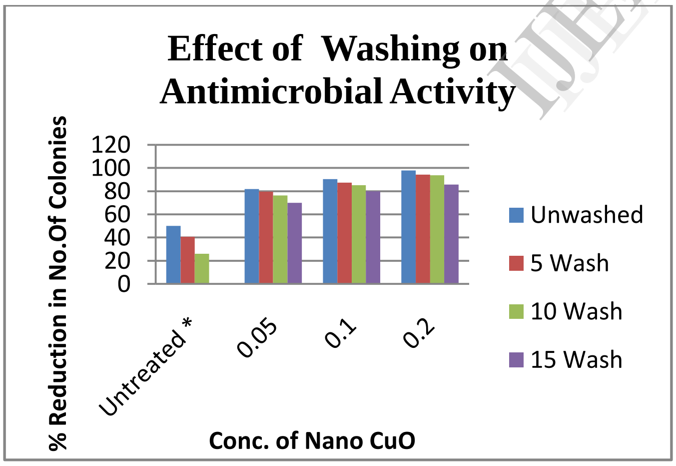


Figure VIII: Effect of Washing on antimicrobial activity of Nano CuO and 70 gpl DMDHEU treated Cotton fabric against *E. Coli*

Any finish applied on the fabric changes the physical properties of the fabric depending on the type of finish applied. Hence, change in physical properties were analyzed by crease recovery angle testing, bending length measurement, tensile strength and elongation measurement.

A comparison of crease recovery angle i.e. the wrinkle resistance property of the fabric of various samples treated with nano copper oxide, a combination of acrylic binder and nano copper oxide, various concentrations of DMDHEU and a combination of DMDHEU with nano copper oxide are illustrated in the **Figures IX - XIII**. As the concentration of nano copper oxide on the fabric increases, the crease recovery angle or wrinkle resistance of the fabric increases to a small extent upto a concentration of 0.1gpl. Further increase in concentration does not further enhance the crease recovery angle. The increase may be due to catalyzing action of nanoparticle on degree of cross linking developed in the fabric. [8] A similar trend is observed where nano copper oxide is applied in combination with Acrylic binder. There is increase in the crease recovery angle which is higher than the samples that were only treated with nano copper oxide which may be attributed to the fact that more amount of cross linking takes place in the presence of binder than without it.

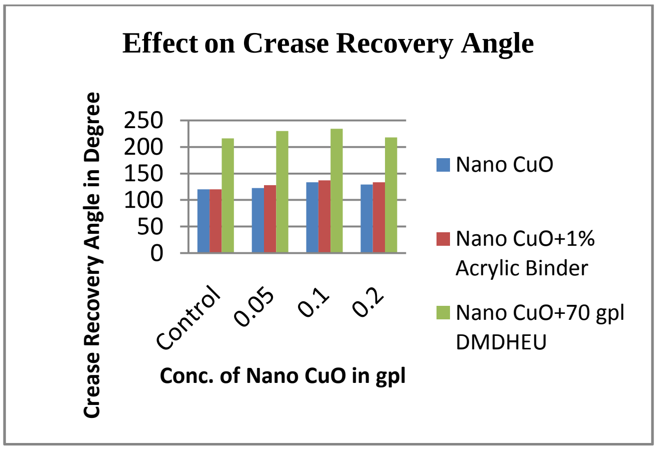


Figure IX: Effect of Nano CuO on Crease Recovery Angle of Cotton fabric

In **Figure X**, crease recovery angles of DMDHEU treated fabrics with three concentrations i.e. 60, 70 and 80gpl are determined and it is observed that there is an enormous increase in crease recovery angle when DMDHEU is applied on the cotton fabric. It is a well known commercial cross linking agent and it successfully cross links the hydroxyl groups of cellulose. From the Figure it can also be seen that beyond 70 gpl DMDHEU concentration there is a drop in the crease recovery angle for obvious reasons that with increase in concentration of DMDHEU resiliency of fabric decreases with commensurate increase in specific density of the fabric. [9] Hence, for best results of wrinkle resistance, a concentration of 70 gpl DMDHEU is optimized.

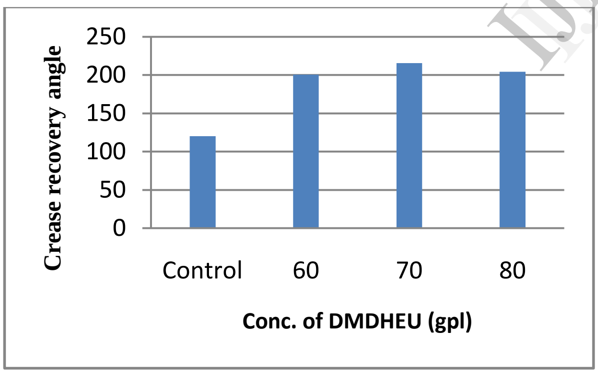


Figure X: Effect of concentration of DMDHEU on Crease Recovery Angle of Cotton fabric

Figure IX indicates the results of crease recovery testing of fabrics treated with nanoparticles in combination with 70gpl DMDHEU and it can be noted that with the addition of nano copper oxide to the DMDHEU treated fabrics, there is an increase in the crease recovery angle or wrinkle resistance of fabric as compared to the only DMDHEU treated fabrics. This increase may be attributed to the fact that nano copper oxide assists in the cross linking of cellulose molecules and probably acts as a co-catalyst for better cross linking to take place with DMDHEU. [8] After a concentration of 0.1 gpl, there is slight decrease in the crease recovery angle but it still remains higher than the fabric treated only with DMDHEU. These results clearly indicate that nano copper oxide and DMDHEU act synergistically and can be used in combination to reduce the number of steps of finishing as well as obtain better results.

Bending length of the fabrics were tested to determine the effect on the stiffness of the fabric. **Figure XI** shows the results of bending length of fabric treated with nano copper oxide, fabric treated with acrylic binder and nano copper oxide, and fabrics treated with a combination of DMDHEU and nano copper oxide. From the figure it can be observed that as the fabric is padded with nano copper oxide particles, there is marginal increase in the bending length which indicates an increase in stiffness, as more length and thus more weight of fabric was required to bend the fabric to a particular angle under normal gravimetrical conditions. Similar results were obtained when the fabric was treated with Acrylic binder and nano copper oxide but the increase is slightly more than that compared to the fabric treated without acrylic binder. This is mostly because the binder imparts some amount of cross linking on the fabric in which the nano particle entraps and this cross linking would bring about increase in stiffness of the fabric.

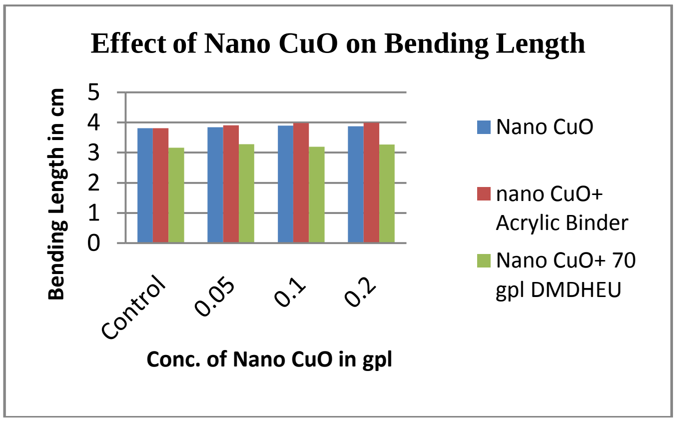


Figure XI: Effect of Nano CuO on Bending Length of Cotton fabric

The figure also demonstrates the effect of combination of DMDHEU with nano copper oxide on the bending length of the fabric. While padding the fabrics with DMDHEU, a softener in the concentration 20 gpl was also added to reduce the stiffness caused on the fabric due to cross linking and thus it can be seen that the bending length of DMDHEU treated fabric gets reduced as compared to the untreated fabric. On the contrary, when we add nano copper oxide along with DMDHEU while padding, the fabrics show an increase in the bending length as compared to only DMDHEU treated fabrics which means that there is an increase in the stiffness. Thus the use of nano copper oxide increases the stiffness of the fabric marginally and the addition of binder enhances this effect.

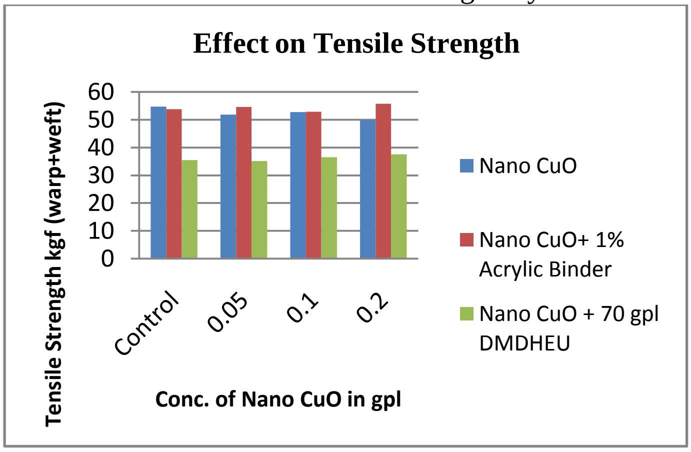


Figure XII: Effect of Nano CuO on Tensile Strength of Cotton fabric

The tensile strength of a fabric is one of the most important attributes of a fabric and most of the finishes effect the tensile strength to the largest extent than any other property. The change in the values of tensile strength of various concentrations of nanoparticle treated fabrics compared with untreated are given in **Figure XII**. There is a decrease in the tensile strength but not very significant. The tensile strength of the fabric goes on decreasing as we go on increasing the concentration of the nano copper oxide particles on the fabric. The trend reverses when these nano particles are applied along with an acrylic binder. When the tensile strength of DMDHEU treated fabric is compared with

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untreated fabric, a huge drop in the tensile strength of the fabric is observed. This may be due to the high amount of cross link formation in the fabric as was evident by the increase in the crease recovery angle. As the amount of cross linking between cellulose chains increases, the freedom of the chains to move or orient themselves freely to overcome external forces reduces, thus making the fabric stiffer. This may result in the huge decrease of tensile strength.

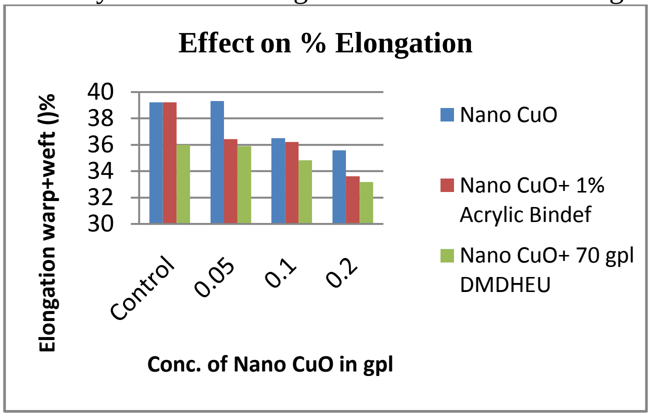
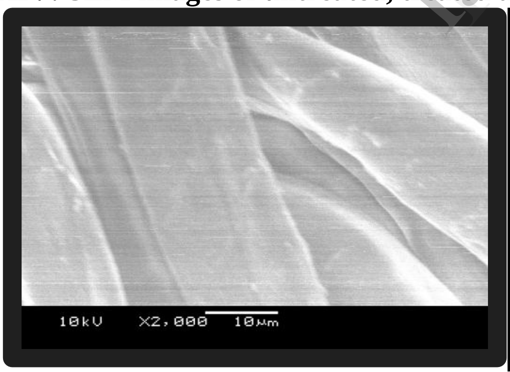
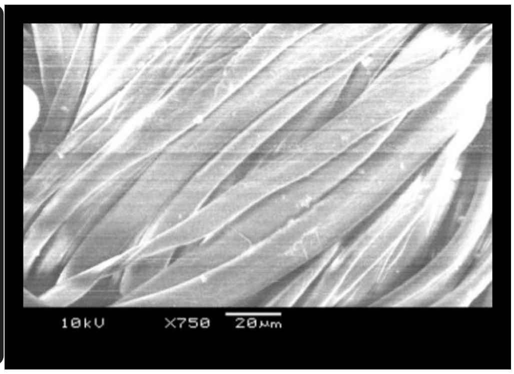


Figure XIII: Effect of Nano CuO on Elongation of Cotton fabric

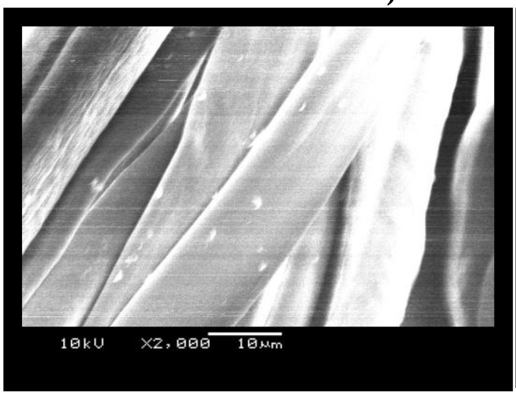
Along with the tensile strength, another factor which is considered is the elongation of the fabric. **Figure XIII** indicates the effect of various treatments on the elongation of the fabric. The results show that all treatments such as application of nano copper oxide, nano copper oxide with acrylic binder, DMDHEU application in combination with nano copper oxide result in decrease in the elongation of the fabric. It is assumed that nano copper oxide causes some amount of cross linking in the fabric thus reducing the elongation of the fabric. Thus as the concentration of nano copper oxide on the fabric increases, the elongation decreases. Acrylic binder as well as DMDHEU enhances this effect as it results in more amount of cross linking and thus the elongation further reduces as compared to the elongation of the fabrics only treated with nanoparticles.

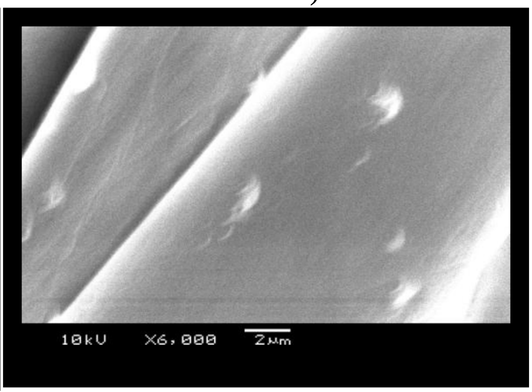
Figure XIV: SEM images of untreated, treated and washed fabrics





A) Untreated B) **Treated**





C) After 5 Wash D**) After 10 Wash**

Surface morphology was studied using SEM. **Fig. XIV** (a) shows there are no nano particles as this is untreated sample, in (b) there are no. of nano particles attached on the surface. In Fig. XIV (c) which is after 5 washes, indicate they are not completely leached away after 5 washes. Fig. XIV (d) shows the nano particles after 10 washes, however the quantity is very low and visible after 6000X zoom. It clearly indicates even after 10 washes few are available.

Conclusion

High purity and crystalline nano copper oxide particles were synthesized by a Direct precipitation method with particle size in the range 40-60 nm and were successfully applied onto cotton to obtain Antimicrobial activity. The Durability of the antimicrobial activity was increased upto 15 washes with the help of Binder. Also,.

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