BREATHABILITY OF WOVEN SURGICAL GOWNS TREATED WITH NANO FINISHES

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CONTENTS

SUMMARY AND CONCLUSIONS

The major conclusions of the study are as follows:

1. Application of nano finish on cotton and P/C fabrics helps to improve the breathability in terms of water vapour resistance, air permeability and wicking as compared to fabrics treated with normal finishes.
2. Nano finished fabrics generally exhibit better drapability. The extent of reduction in tensile and tear strength that is normally associated with the finishing of fabrics is relatively less for nano finished specimens.
3. Durability of nano finished fabrics is better than that of fabrics finished with normal chemicals. Application of nano finish on cotton and P/C fabrics is found effective in controlling the bacterial growth even after 50 home launderings against gram positive bacteria (S.Aureus). For gram negative organism (E.Coli), the type of nano finish used in the study is effective for fabrics with minimum number of washings.
4. Application of nano finish on P/C fabrics helps to maintain the liquid repellent property upto 50 home launderings.

1.0 INTRODUCTION

Surgical gowns & surgical face masks are important components of surgical apparels. They are expected to perform as barriers and provide increased protection to the health care workers. There continues to be a growing demand from operation theatre staff for improved security and protection against blood and liquid borne pathogens, especially against viruses such as Hepatitis B.

On a global basis, single use non-woven products are now used in about 60 – 70% of all surgical interventions[1, 2]. However, in India, majority of the hospitals use only woven products for surgical apparels (particularly surgical gowns). The woven gowns are washed and sterilized before use.

Recent research studies suggest that some reusable surgical apparels fail in terms of quality standards and could endanger patients[2]. Hence, the surgical apparels are necessarily to be treated with appropriate antibacterial and liquid repellent finishes to provide adequate protection against cross infection. However, the finishing treatment on the surgical apparels should not affect the breathability if the apparels are to be accepted by the operation theatre staff.

Recently, nano finishes were introduced in the market and as per claims[3] nano finishes do not affect the breathability of treated fabrics. However, no published data is available in this aspect. The present study is for generating relevant information in this area.

2.0 MATERIALS AND METHODS

Plain weave cotton and P/C woven dyed fabrics (mostly used in woven surgical gowns) are taken in this study. Cotton fabrics are dyed with vat dyes and polyester/cotton fabrics dyed with disperse and vat dyes. The specifications of cotton and polyester/cotton fabrics are given in table 1.

Table 1 Specification of cotton and P/C fabrics

S.No	Particulars	Cotton fabrics	P/C fabrics
1.	Count – Warp Weft	20^s 20^s	$2/40^s$ $2/40^s$
2.	Ends/Inch (EPI)	60	60
3.	Picks/Inch (PPI)	56	56
4.	Cover factor	19.94	19.94
5.	Weave	Plain	Plain

These fabrics are given antimicrobial and liquid repellent treatment using normal and nano finishing chemicals (obtained from one particular brand). Antimicrobial property is obtained by the application of normal Zinc oxide (ZnO) and nano silver over the fabric, whereas liquid repellent property is obtained using normal and nano fluorocarbons.

2.1 Chemicals Used

Tables 2 and 3 show the various chemicals used for antimicrobial finishing of cotton and P/C fabrics.

Table 2 Chemicals used for normal antimicrobial finishing

S.No	Commercial Name	Chemical Name	Purpose	Application Concentration (g/l)
1.	Biozyde-B	Normal ZnO	Antimicrobial agent	40
2.	Acetic acid	Acetic acid	To control the acidity of the solution	1

Table 3 Chemicals used for nano antimicrobial finishing

S.No	Commercial Name	Chemical Name	Purpose	Application Concentration (g/l)
1.	ISYS MTX	Organic-inorganic binder	To bind the silver nano particles with the specimen.	15
2.	ISYS AG	Nano silver	Antimicrobial agent	3
3.	Tubingal RGH	Silicone	Softener	40
4.	Kollosol CDO	Hydrophilic silicone compounds with higher alcohols	Defoaming agent	1

Tables 4 and 5 show the chemicals used for liquid repellent finishing of cotton and P/C fabrics.

Table 4 Chemicals used for normal liquid repellent finishing

S.No	Commercial Name	Chemical Name	Purpose	Application Concentration (g/l)
1.	Tubiguard SR Ultra-X	Normal fluorocarbon	Liquid repellent finish	65
2.	Kollosol CDO	Hydrophilic silicone compounds with higher alcohols	Defoaming agent	1

Table 5 Chemicals used for nano liquid repellent finishing

S.No	Commercial Name	Chemical Name	Purpose	Application Concentration (g/l)
1.	Nanoprove FC	Nano fluorocarbon	Liquid repellent finish	40
2.	Acetic acid	Acetic acid	To control the acidity of the solution	1

Cotton and P/C fabrics are finished with antimicrobial and liquid repellent chemicals by means of padding-drying-curing method. Finished fabrics are dried at 120°C and subsequent curing is done at 160°C.

The efficiency and durability of nano finishing of fabrics is evaluated and compared with that of relevant normal finishing chemicals. The antimicrobial and liquid repellent properties of fabric samples (untreated, treated with normal finish & treated with nano finish) are evaluated as per relevant standards.

3.0 RESULTS AND DISCUSSION

3.1 Breathability of fabric

Breathability of a fabric is mainly determined by three factors, namely water vapour resistance, air permeability and wicking[4].

3.1.1 Water vapour resistance

Water vapour resistance of a fabric denotes the extent to which the water vapour gets passed on to the atmosphere through the fabric sample[5]. It is evaluated using sweating guarded hot plate tester at SITRA. A brief description of working of the instrument is given in appendix-I. Table 6 gives water vapour resistance of antimicrobial (normal and nano) and liquid repellent (normal and nano) cotton and P/C fabrics.

Table 6 Water vapour resistance of untreated and treated (normal and nano finished) fabric samples

S.No.	Type of fabric	Water vapour resistance of fabric - R_{et} [(m^2. Pa)/watt]				
		Untreated sample	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	3.3	3.92	3.4	4.12	3.32
2.	P/C fabrics	3.64	4.3	3.73	4.20	3.70

Water vapour resistance of nano finished fabric samples is less by about 12 - 20% as compared to that of fabrics treated with normal finishing chemicals. This would imply that nano finished fabrics (both cotton as well as P/C fabrics) are comfortable to wear.

3.1.2 Air permeability

Air permeability is another property deciding the comfort of the fabric. Table 7 gives air permeability of antimicrobial (normal and nano) and liquid repellent (normal and nano) fabric samples.

Table 7 Air Permeability of untreated and treated (normal and nano finished) fabric samples

S.No	Type of fabric	Air Permeability of fabric ($cm^3/cm^2/sec$)				
		Untreated sample	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	102	94.5	100	93.9	101.0
2.	P/C fabrics	21	18.2	19.6	17	20

Nano silver and nano fluorocarbon treated cotton and P/C fabrics have relatively higher air permeability as compared to that of normal finished cotton and P/C fabrics by 8 to 18%. Nano finishes deposit mainly on the fibre surface and hence they do not lock the pores in the fabrics.

In the case of normal finishing, due to the bigger molecule size of chemicals, locking of pores do occur. This is the reason why nano finished fabric specimens have relatively higher air permeability.

3.1.3 Wicking

High and uniform absorbency is a desirable quality in all the finished fabrics. Absorbency of fabric is influenced by their wicking ability. Wicking occurs when a fabric is completely or partially immersed in a liquid or in contact with a limited amount of liquid such as drop placed on a fabric. Table 8 gives wickability of antimicrobial (normal and nano) and liquid repellent (normal and nano) fabric samples.

Table 8 Wicking of untreated and treated (normal and nano finished) fabric samples

S.No	Type of fabric	Wicking (Rise of liquid level in mm in the specimen after 30 min)				
		Untreated sample	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	110	90	100	-	-
2.	P/C fabrics	160	140	150	-	-

Nano finished fabric samples have higher wicking as compared to that of samples treated with normal finishing chemicals. This would imply that nano finished fabric samples have better comfort by 8 – 10%.

3.2 Physical properties

3.2.1 Tensile strength

Tensile strength of antimicrobial (normal and nano) and liquid repellent (normal and nano) cotton and P/C fabrics are given in table 9. From the table, it is clear that the tensile strength of nano finished fabrics is more or less as that of normal finished fabrics in the case of cotton. In the case of P/C fabrics, nano finished specimens show higher tensile strength to the tune of 3 to 4% as compared to that of normal finished fabrics. Hence the strength reduction that is normally associated with the finishing of fabrics is relatively less in the case of nano finishing.

Table 9 Tensile strength of untreated and treated (normal and nano finished) fabric samples

S.No.	Type of fabric	Tensile Strength (kgf)				
		Untreated fabric	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	38.36	34.81	35.53	36.66	37.02
2.	P/C fabrics	85.21	80.86	84.35	80.68	83.26

3.2.2 Tear strength

Tear strength of antimicrobial (normal and nano) and liquid repellent (normal and nano) cotton and P/C fabrics are given in table 10.

Tearing strength of nano finished cotton and P/C fabrics are more or less or at the same level as that of normal finished fabric samples.

Table 10 Tear strength of untreated and treated (normal and nano finished) fabric samples

S.No.	Type of fabric	Tear Strength (gf)				
		Untreated fabric	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	1043	998.6	1020.2	1010.6	1021.8
2.	P/C fabrics	1982.6	1897.5	1945.4	1920.8	1953.4

3.2.3 Draping behaviour

Draping behaviour of antimicrobial (normal and nano) and liquid repellent (normal and nano) cotton and P/C fabrics are given in table 11. Nano finished fabrics show lesser drape co-efficient than normal finished fabrics by 3 to 6%, hence the drapability of nano finished fabrics is better.

This is attributed to the fact that in the case of nano finishes, nano particles are deposited only on the fiber surface, whereas in the case of normal finishes, the molecules are deposited both on the fiber surface as well as on the fabric pores.

Table 11 Draping behaviour of untreated and treated (normal and nano finished) fabric samples

S.No.	Type of fabric	Drape (%)				
		Control sample	Antimicrobial finish		Liquid repellent finish	
			Normal	Nano	Normal	Nano
1.	Cotton fabrics	69.3	73.39	71.96	72.77	70.08
2.	P/C fabrics	62.7	68.6	64.5	65.16	63.04

3.3 Characterization analysis

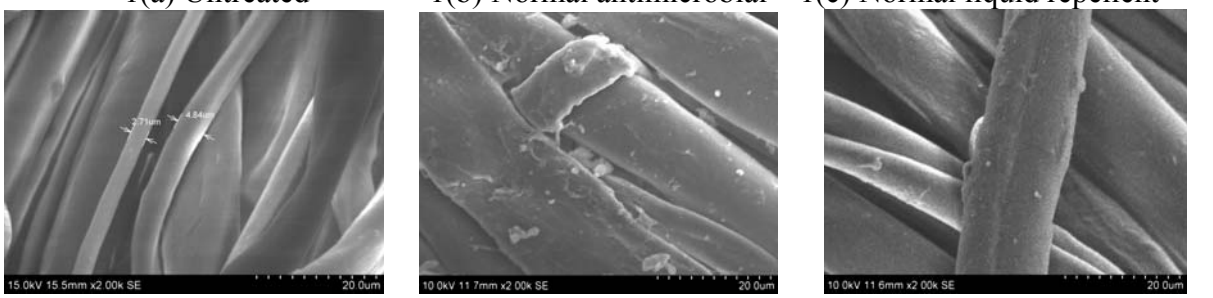
3.3.1 SEM evaluation

Scanning Electron Microscope is used to identify morphological structure of specimens (fiber, yarn or fabric) under investigation. SEM evaluation is also used to know the uniformity of coating of finishing chemicals over the specimen. SEM images of cotton and P/C fabric samples (untreated and treated) are shown in figures 1 & 2.

The nanoscaled silver and fluorocarbon particles are observed on cotton and polyester/cotton fabric samples (figures 1e, 1f & 2e, 2f). The nanoparticles are well dispersed on the fibre surface in both the cases and show homogeneous distribution in the coating layer, thus making the coated fabrics to have uniform antimicrobial and liquid repellent property.

The particle size plays a major role in determining their adhesion to the fibre molecules[6]. Generally agglomeration of large particles will get easily removed from the fibre surface, while the small particles will penetrate deeper and adhere strongly into fabric matrix.

1(a) Untreated 1(b) Normal antimicrobial 1(c) Normal liquid repellent



1(d) Untreated 1(e) Nano antimicrobial 1(f) Nano liquid repellent

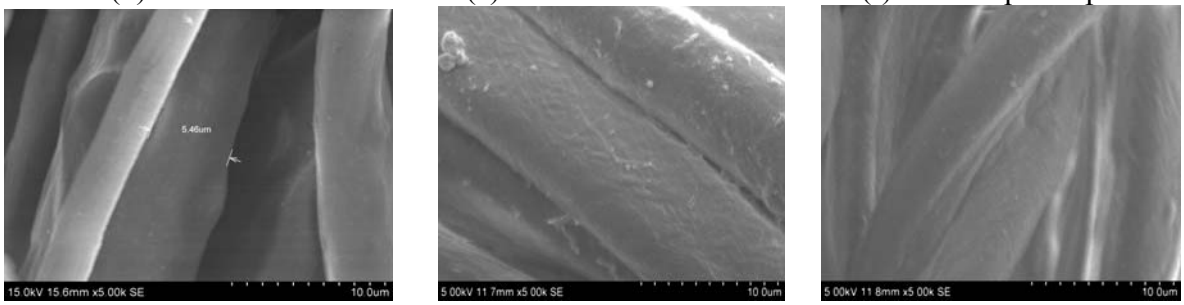
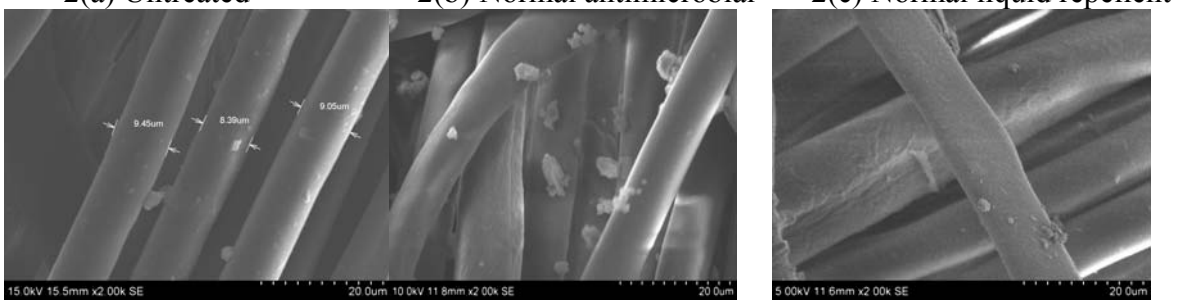


Fig 1 SEM images of untreated and treated (normal and nano finished) cotton fabric samples.

2(a) Untreated 2(b) Normal antimicrobial 2(c) Normal liquid repellent



2(d) Untreated 2(e) Nano antimicrobial 2(f) Nano liquid repellent

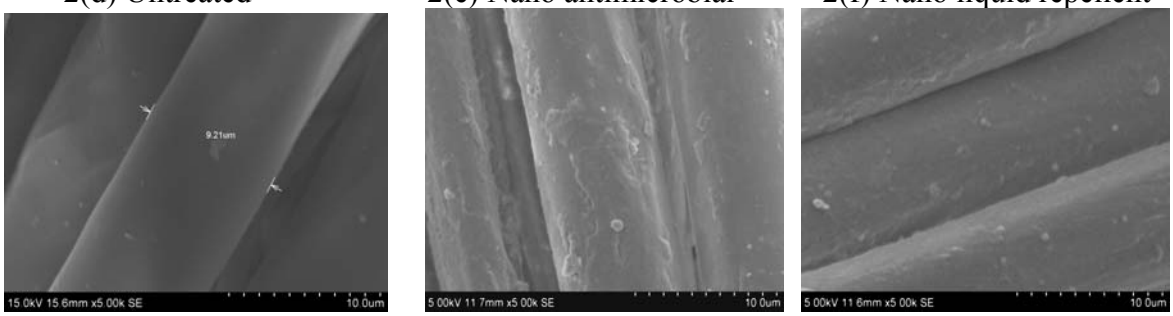


Fig 2 SEM images of untreated and treated (normal and nano finished) P/C fabric samples.

3.3.2 FTIR evaluation

Fourier transform infrared spectroscopy (FTIR) is an analytical tool to identify the nature of chemicals that are coated on the fabric specimen. It also helps to know to what extent the molecules of the finishing chemicals are attached with fibre molecules of the specimen. FTIR spectrum of untreated and treated cotton fabrics are shown in figures 3, 4&5.

From the IR spectrum analysis, it is evident that normal & nano fluorocarbon are reacting differently with OH groups of cotton fabrics via `H' bonding.

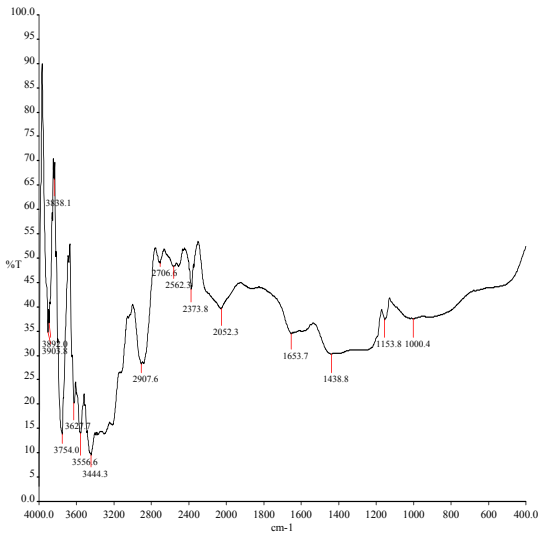


Fig 3 FTIR spectrum of untreated fluorocarbon
treated cotton fabrics

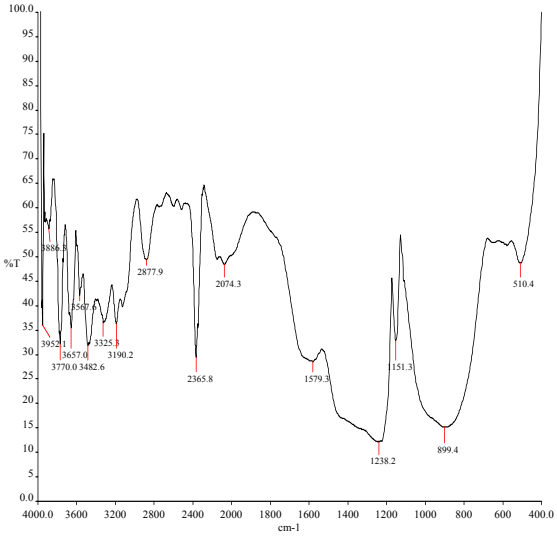


Fig 4 FTIR spectrum of normal cotton fabrics

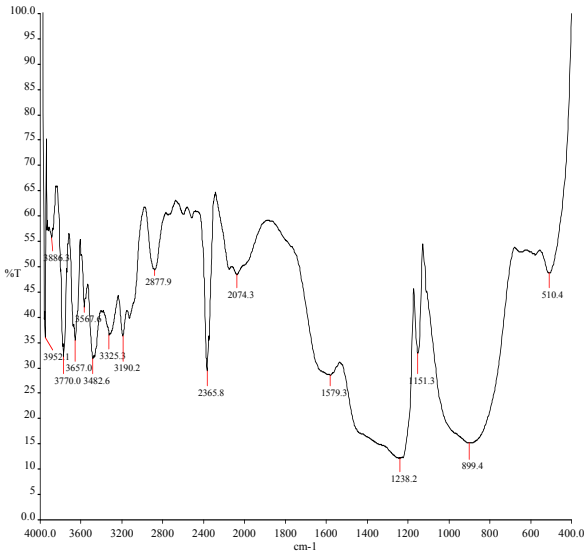


Fig 5 FTIR spectrum of nano fluorocarbon treated cotton fabrics

The OH stretching vibrations of specimen treated with chemicals could be measured using FTIR and they are expressed in terms of wave number. The OH stretching vibration of cotton in the presence of normal & nano fluorocarbon derived from the spectra is presented and compared in table 12. The data indicate the OH vibrations of cotton occur at higher wave number when coated with normal fluorocarbon and at relatively lower wave number when coated with nano fluorocarbon. This observation suggests that fluorine of nano fluorocarbon reacts strongly with the OH groups of cotton thus making stronger bonds.

Table 12 FTIR spectrum wave number of treated fabrics

Specimen type	**Wave number (λ)**					
Normal fluorocarbon coated cotton fabrics	3770	3657	3567	3482	3325	3193
Nano fluorocarbon coated cotton fabrics	3767	3509	3398	3313	3204	3100

3.3.3 Particle size analysis using dynamic light scattering (DLS) technique

Dynamic light scattering technique is used to measure the size of the particles, typically in the submicron region, present in the finishing chemical. Distribution curve (by intensity) of nano fluorocarbon obtained using DLS technique is given in figure 6. In this study, solution of nano fluorocarbon is used.

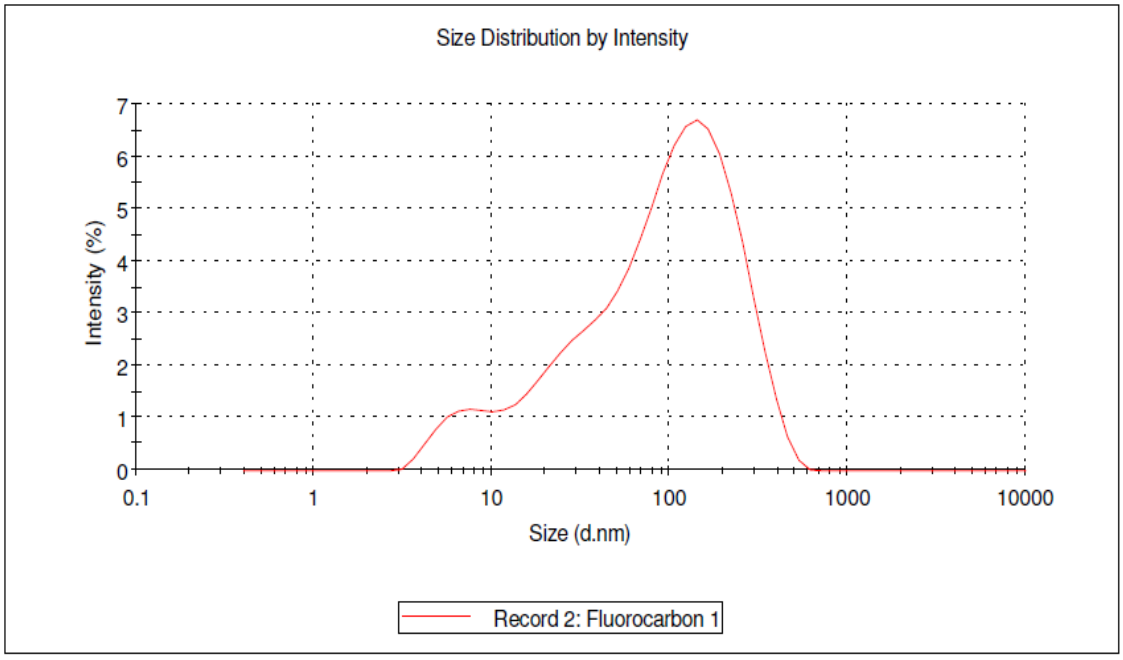


Figure 6 Distribution curve (by intensity) for nano fluorocarbon

From the intensity size distribution, hydrodynamic diameter of the particles in the nano solution is calculated using strokes – Einstein equation,

$$R_H = (K_B\ T) / (6\ \pi\ \eta\ D_T)$$

Where,

R_H = hrdrodynamic diameter,

K_B = Boltzmann's constant (1.38×10^{-23} $m^2kgs^{-2}k^{-1}$).

T = absolute temperature

η = viscosity

D_T = diffusion coefficient

In the present case, the average size of the nano particles is found to be in the region of 52 nm.

3.4 Durability of nano finishing

Durability of antimicrobial and liquid repellent finished cotton and P/C fabrics (normal and nano) are discussed in this section.

3.4.1 Antimicrobial activity for gram positive (for S.Aureus) organism

Cotton and P/C fabrics are finished with normal and nano antimicrobial agents to provide antimicrobial activity against micro-organisms.

In order to assess the durability of the finishing treatment, the percentage reduction in the number of bacteria present (between untreated control specimen and treated test specimen) in normal and nano finished antimicrobial cotton and P/C fabrics against gram positive organism (S.Aureus) for different number of home launderings is calculated and given in table 13.

Table 13 Reduction in the number of bacteria (for S.Aureus) of treated cotton and P/C fabrics.

S.No.	Type of fabric used	% Reduction in number of bacteria			
		Cotton fabrics		P/C fabrics	
	Type of finish	Normal	Nano	Normal	Nano
	Test condition				
1.	After treatment (Before wash)	100	100	100	100
2.	After 10 washes	50	100	91	100
3.	After 20 washes	45	100	76	100
4.	After 30 washes	36	100	68	100
5.	After 40 washes	33	100	60	100
6.	After 50 washes	30	100	54	100

* Reduction was calculated taking into consideration the number of bacteria present in treated test specimen and untreated control specimen.

It is discernible from the table that, the percent reduction in the number of bacteria present is same for normal and nano finished fabrics before any washing. However, after launderings nano finished fabric samples exhibit superior performance. Even after 50 home launderings, percent reduction in bacteria present remains the same in these fabric samples. On the other hand, the durability of the treatment reduces

considerably with fabrics treated with normal finish. For example between cotton fabrics with zero wash and fabrics with 50 wash (both treated with normal finish), the % reduction in bacteria present (between treated and control samples) reduces by 70% (absolute value). In the case of P/C fabrics, the corresponding reduction is around 50 % (absolute value).

3.4.2 Antimicrobial activity for gram negative (E. Coli) organism

The percentage reduction in the number of bacteria present (for gram negative organism) is given in table 14 for normal and nano finished antimicrobial cotton and P/C fabrics.

For gram negative organism, the type of normal finish used in the study is found to have no influence in controlling the bacterial growth i.e. between untreated and treated (using normal finish) fabric samples, there is no difference in the amount of bacteria present after inoculation and incubation.

In cash of nano finished fabric samples, the antimicrobial activity is found for fabrics without any washing. With washing the extent of antimicrobial activity deteriorates drastically. Therefore, for gram negative organism (E.Coli), the type of nano finish used in the study is effective for fabrics with minimum number of washings.

Table 14 Reduction in the number of bacteria (for E. Coli) of treated cotton and P/C fabrics.

S.No.	Type of fabric used	% Reduction in number of bacteria			
		Cotton fabrics		P/C fabrics	
	Type of finish	Normal	Nano	Normal	Nano
Test condition					
1.	After treatment (Before wash)	0	100	0	100
2.	After 10 washes	0	57	0	63
3.	After 20 washes	0	36	0	33
4.	After 30 washes	0	21	0	28
5.	After 40 washes	0	18	0	25
6.	After 50 washes	0	15	0	21

3.4.3 Durability of liquid repellent finishing

Liquid repellency of P/C fabric samples treated with normal and nano finishing chemicals is discussed in this section. The method of testing carried out to assess the liquid repellent property of fabric specimens is given in appendix II.

Table 15 shows the repellency of normal and nano finished P/C fabrics. From the table it is discernible that, normal finished P/C fabrics provide repellency for short duration (5 minutes-upto 30 washes). In the case of nano finishing, repellency characteristic is observed even after 1 hour and upto 50 washes.

Table 15 Blood repellency of normal and nano finished P/C fabrics

S.No	Sample description	After 5 min	After 1 hr
1.	P/C fabrics-Normal finish 10 washes	Pass	Fail at 30 min
2.	P/C fabrics-Normal finish 20 washes	Pass	Fail at 8 min
3.	P/C fabrics-Normal finish 30 washes	Pass	Fail at 5 min
4.	P/C fabrics-Normal finish 40 washes	Fail at 3 min 18 sec	-
5.	P/C fabrics-Normal finish 50 washes	Fail at 2 min 04 sec	-
6.	P/C fabrics-Nano finish 10 washes	Pass	Pass
7.	P/C fabrics-Nano finish 20 washes	Pass	Pass
8.	P/C fabrics-Nano finish 30 washes	Pass	Pass
9.	P/C fabrics-Nano finish 40 washes	Pass	Pass
10.	P/C fabrics-Nano finish 50 washes	Pass	Pass

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REFERENCES

1 Geoff Fisher, "Development Trends in Medical Textiles – Surgical Gowns and Drapes", ATA Journal for Asia on Textile & Apparel, February 2006, http://www.adsale.com.uk

2 Indra Doraiswamy and K.P.Chellamani, "Recent Advance in Medical Textiles", Asian Textile Journal, December 2008, p 49 -55

3 Mangala Joshi, "Nanotechnology – Applications in Textiles", Nano Technology, Asian Dyer, December 2006, p. 49 -52.

4 B. K. Behera and H. Arora, "Surgical Gown: A Critical Review", J Ind Textiles, Vol.38, p.205-231, 2009.

5 B. Tomsic, B. Simonc and B. O. Lidija, "Sol–Gel Coating of Cellulose Fibers with Antimicrobial and Repellent Properties" J Sol-Gel Sci Technol, Vol.47, p.44-57, 2008.

6 M. G. A. Castanon, N. Nino-Martinez, F. Martinez-Gutierrez, J. R. Martinez-Mendoza and F. Ruiz, "Synthesis and Antibacterial activity of Silver Nanoparticles with different sizes", J Nanopart Res, Vol.10, p.1343–1348, 2008.

APPENDIX – 1

WATER VAPOUR RESISTANCE - EN 31092:1993

Assessment of water vapour resistance in textile materials is determined by rate at which water vapour gets passed on to the atmosphere through the fabric sample. This is done with the help of sweating guarded hot plate tester.

The specimen to be tested is placed on an electronically heated porous plate with conditioned air ducted to flow across and parallel to its upper surface. Then the water vapour resistance (Ret) is calculated using the formula,

$$R_{et} = \frac{(P_m - P_a).\ A}{H - \Delta H_e} - R_{et0}$$

Figure 7 Specimen loading chamber of sweating guarded hot plate tester

Where,

P_m is the saturation water-vapour partial pressure, in Pascal, at the surface of the measuring unit at temperature T_m

P_a is the water-vapour partial pressure, in Pascal, of the air in the test enclosure at temperature T_a

A is the area of the measuring unit, in square meter.

H is the heating power supplied to the measuring unit in watt.

ΔH_e is the correction term for heating power for the measurement of water-vapour resistance R_{et}

R_{et0} is the apparatus constant in square meters Pascal per watt, for the measurement of water-vapour resistance R_{et} (4.67 m^2.Pa/watt).

APPENDIX – II

METHOD OF ASSESSING LIQUID REPELLENT PROPERTY OF FABRIC SPECIMENS

A 100 ml (Rivera) beaker is filled with 100ml quantity of synthetic blood. The mouth of the beaker is covered with sample face side, and then it is inverted and placed on the stand. After 5 minutes as well as after 1 hour, the back side of the sample is observed for the presence or absence of the synthetic blood.