Enhancing Medical Textiles Functionalities by Nanotechnology Treatment

Faiza F.S.Ebrahim[1] & Gihan E.H.Ali[2]

[1]Academy of Specialized Studies, Nasr City, Cairo, Egypt
[2]Faculty of Science & Education, Taif University, Kingdom Saudi Arabia
f_wutext@yahoo.com

Abstract: The use of medical textile and fibrous materials are already prevalent in the healthcare sector. This paper investigates the possibility to improve the comfort and functionality of these textiles with nanotechnology by assessing all of the above concerns and compare the benefits of nanotechnology with its disadvantages. Fabric comfort is determined by its physical and mechanical properties which are being influenced by the finishing treatment. This paper studies the effects of Nano-silver finishing on the physical and mechanical properties. Twill 1/3 weave of 100% cotton fabrics have been finished with five distinct solutions concentrations (100,200,300,400 and 500 PPM) and have been compared to the raw fabric. The physical and mechanical properties including air permeability, water permeability, water repellency, bacterial &microbe numbers, elongation, tensile strength, soil release, static protection and weight have been measured. The results illustrated that by increasing the solution concentration of the Nano-silver finish, air permeability, water repellency thickness, tensile strength, soil release and weight have been increased and there is a great difference between Nano-finished samples and the unfinished one. Also by increasing the solution concentration, a great decrease in water permeability, bacterial &microbe numbers, elongation and static protection. Also an irregular increase in thickness. All these consequences have been confirmed by the mean of statistical analysis.

[Faiza F, Gihan E. **Enhancing Medical Textiles Functionalities by Nanotechnology Treatment.** *J Am Sci* 2014;10(11):191-197]. (ISSN: 1545-1003). http://www.jofamericanscience.org. 26

Keywords: Nanotechnology; Cotton; physical and mechanical properties, medical textiles, Nano-silver finish

1. Introduction

Medical textiles known as Healthcare Textiles. Medical Textiles is one of the most rapidly expanding sectors in the technical textile market. It is one of the major growth areas within technical textiles and the use of textile materials for medical and healthcare products ranges from simple gauze or bandage materials to scaffolds for tissue culturing and a large variety of prostheses for permanent body implants. Textile products are omnipresent in the field of human hygiene and medical practice. Their use is based on a number of typical basic textile properties like softness and lightness, flexibility, absorption, filtering[1]. Advanced medical textiles are significantly developing area because of their major expansion in such fields like wound healing and controlled release, bandaging and pressure garments, implantable devices as well as medical devices, and development of new intelligent textile products. Present day society is undergoing changes like large population size, need of increasing his life span of every individual, various situations and hazards of human activity and civilization including transport accidents, chemical materials, fire, cold, diseases, and sports. Such factors increase the demand of medical textiles. So there are several researching works are going on all over the world in medical textile materials and polymers [2]. Nanotechnology, the manipulate Nano-technique has acquired tremendous impulse in the last decade. Nano-fiber based products as well as Nano-coated materials are present innovations in the field of medical. So in our technical poster we have gone through latest medical textiles, Nano-based products due to following features and wide range of application.Nano-technique has acquired tremendous impulse in the last decade. Nano-fiber based products as well as Nano-coated materials are present innovations in the field of medical. So in our technical poster we have gone through latest medical textiles, Nano-based products due to following features and wide range of application. Nanofibres are very attracted due to their unique properties, high surface area to volume ratio, film thinness, Nano scale fiber diameter porosity of structure, lighter weight. Nanofibres are porous and the distribution of pore size could be of wide range, so they can be considered as engineered scaffolds with broad application in the field of tissue engineering. Some other applications like wound dressings, bone regeneration and nanofibres to be the carrier of various drugs to the specific sites, etc.[3].

The consumption of Medical Textiles worldwide was 1.5 million tons in 2000 and is growing at an annual rate of 4.6%. The Indian market size of medical textiles was estimated to be INR 14.8 billion in 2003-04 and is expected to grow to INR 23.3 billion by 2007-08. Market is expected to grow by 8% p.a[4]. Medical Textiles are the products and constructions used for medical and biological applications and are used primarily for first aid, clinical and -hygienic purposes. It consists of all those textile materials used in health and hygienic applications in both consumer and medical markets. As such it comprises a group of products with considerable variations in terms of product performance and unite value. Because of the nature of their application many medical products are disposable items. The increased use of textiles in composite applications will provide major growth fiber consumption in terms of volume [5].The traditional applications include wound care products, diapers, braces, prostheses and or hoses, wipes, breathing masks, bedding and covers, ropes and belts etc. Innovative textile products can both add significantly to effectiveness of medical treatments as well as patient comfort At the same time, new medical textiles, may contribute to cost containment [6]. Such innovative products Provide new treatment options (textile based implants instead of scarce donor organs; artificial tissues, joints and ligaments), Speed up recovery after medical treatment (innovative wound dressings; light, Breathable orthoses/ prostheses). Enhance quality of life of chronically ill people (functional clothing), surgeons wear, wound dressings, bandages, artificial ligaments, sutures, artificial liver/kidney/lungs, nappies, sanitary towels, vascular grafts/heart valves, artificial joints/bones, eye contact lenses and artificial cornea and the like are some of the examples of medical textiles. Medical textiles are textile products and constructions for medical applications. They are used for first aid, clinical or hygienic purposes and rehabilitation [7]. The application of nanotechnologies to textiles affords an expanded array of properties with potential for improved and novel use in materials and products. Changed or improved properties with nanotechnologies can provide new or enhanced functionalities. How are these realized in materials and processes? How do they appear in end products? The information presented in this section is not exhaustive, but does reflect current national and international research, and commercial activities in Nano textiles [8]. Antimicrobial textiles include anti-odour, antifungal and antibacterial textiles. This applies to products whose fibers possess intrinsic bactericidal properties or will acquire them through subsequent treatments (chemical finishing, nanotechnologies, addition of bactericidal metals, etc.). Products have potential applications in apparel and intimate apparel, but also in a number of non-apparel applications (furniture, carpets, etc.). These textiles significantly reduce or even eliminate traditional textile-care operations (washing, spin drying, drying, ironing). Properties include spill, wrinkle, oil and stain resistance [9].Many products use, or with commercialization will use, chemical, physical or electronic technologies to respond passively or actively to thermal, chemical, biological, electromagnetic and mechanical stress. These products include warming and cooling textiles, conductive textiles, communicating textiles, textile sensors and actuators, digital fashion, chromatic textiles, etc., with applications in the medical field, sport and leisure, the military and first-responders market, and intelligent applications in buildings. These are properties and applications with potential to provide value in products. Some can be achieved by conventional means, e.g., wrinkle resistance, but with research, alternatives or improved means via nanotechnologies may be found. Lower processing costs, less energy usage or reduced chemical processing may be other value-added factors resulting from the use of nanotechnologies. Much of this is at a research/concept stage, with some application in products now. How is this being achieved in textiles? Integration of nanotechnologies into textile products is being realized in coatings, treatments, fiber material composites and Nano scale fibers. Nano textiles have been subdivided into four major types [10]:i. Nano finished textiles are those that apply a Nano scale property added after the base textile has been fabricated. This includes post-manufacture treatments and coatings to apply nanomaterial or create nanostructured surfaces on fiber media. Additive nanomaterial's to date include metal Nano-objects (such as silver for antimicrobial functionality) or clay Nano-objects (for fire resistance). Nanostructured surfaces may include those roughened by treatments (hydrophobicity for self-cleaning)[11].For existing process lines, Nano finished textiles may only require the addition of intermediate steps for coating or treatment. The majority of Nano textiles already on the consumer market fall within this category. Nano finishing can provide accessible means for established textile manufacturers to engage with Nano textiles [12].ii. Nano composite textiles have composite fiber materials containing one or more nanostructured or Nano scale components. This type of Nano textile centers upon pre-manufacture integration of Nano scale properties into fibrous components. The source materials added to produce the Nano composite textile include, for example, carbon nanotubes (for enhanced fiber strength) and rare earth metal doped nanoparticles (for luminescence). Polymer matrices are the most prevalent in Nano composite fibers; however, other matrices may also be useful. Similar to Nano finished textiles, Nano composite fibers may not require significant changes to the manufacturing process. If the matrix material is the same shape and size as the process has been designed for, only small alterations may be necessary to integrate the composite component. If the fiber material is entirely changed by choosing a different matrix material or significantly altered by the composite properties, significant reconfiguration may be needed. Alterations to the base material achieved at the research level may face challenges in scaling up to production to realize a stable composite material. These Nano textiles have promise, but currently represent a relative minority in commercialized form [13].iii; Nano fibrous textiles have fibers with Nano scale dimensions. These true nanofibres have a Nano scale cross-sectional area and may or may not have a Nano scale length. Fiber material may be either a single material or a composite (which, based on the fiber dimensions, may also be a Nano composite). Nanofibres may also be Nano finished. These Nano textiles focus on fabricating fibers to exploit Nano scale properties. These properties may emerge either from the nanomaterial composition (such as fibers made of carbon nanotubes, giving them very high strength) or from the scale of the individual fibers (such as filter media, giving them increased fiber surface area and Nano scale porosity) [14].Fiber fabrication for Nano fibrous textiles typically would be new. Not only does initial fabrication of the fiber require a process that can create nanofibres (such as electro spinning or force spinning, which are not conventional drawing methods), but all of the subsequent steps in the manufacturing process must accommodate these smaller fibers. For woven textiles, the technology does not exist on an industrial scale to weave fibers of this size. Beyond that, dyestuffs and laminations may have to be reformulated for nanofibres. Some means of incorporating nanofibres into textiles may be accomplished through entangling or encapsulating the fibers in a larger fiber. While research into Nano fibrous textiles is widespread, little has reached significant commercialization. Its development, however, may afford exciting applications and opportunities [15]. Nano-enabled nonwovens, nanotechnologies in nonwovens may make use of improvements in properties to benefit textile processing; for example, adhesive properties may be enhanced or conventional methods of securing layers replaced with adhering nanostructured surfaces. Other Nano scale functionalities may utilize Nano films or coatings in layers or barriers; for example, for antibacterial properties, energy production (for solar power) and luminescence (for colour control) [16].

2. Materials and Methods

2.1Materials

Fabrics were woven with100% cotton and Twill weaves; 3/1their complete specifications are demonstrated in Table1. Six different specimens were tested in order to study the effects of Nano-silver finishing on the physical and mechanical properties of the fabric. The unfinished sample is labeled 'A' and samples which were finished with five solution concentrations of 100 PPM,200 PPM,300 PPM,400 PPM and 500 PPM are labeled as 'B', 'C', 'D', 'E' and 'F' respectively. Five different concentrations thus have been chosen to identify a trend in changes.

2.2. Treatment condition

In this case, fabrics soaked in 50°c suspensions with five distinct concentrations of Nano silver particles for 30 minutes. Fabrics have been dried in the open air afterward. This kind of finishing is generally called 'exhausting finishing'. PPM stands for particle per million and it is the mass concentration of the batches.

Table (1) Constructional Parameters of Fabric Samples before treatment

Sample ID	Yarn count (Nm)Warp	Yarn count (Nm)Weft	Warp density (ends/cm)	Weft density (picks/cm)	Thickness mm	Weave	F. weight g/m^2
A	32	32	36	36	0. 32	Twill3/1	210

Table (2) Physical &Mechanical Properties of Fabric Samples

	Physical & Mechanical Properties after treatment									
	(A.P)	(W.P)	(W.R)	(B.N)	(T)	(E)	(T.S)	(S.R)	(S.P)	(W)
ID	Cm^3/cm^2.sec	L/m^2.sec	Rate	CFU/g	mm	%	kg	level	kv	g/m^2
A	14.44	0.445	0	880	0.32	28	38	1	11	210
B	15.66	0.442	100	369.6	0.327	16	57	3	8.1	218
C	15.75	0.442	100	350.1	0.327	15.8	57	4.2	7.8	220
D	15.77	0.441	100	332.3	0.327	15.1	60	4.2	7.8	220
E	15.77	0.441	100	290.2	0.327	14.5	55	4.2	7.2	222
F	15.78	0.440	100	277.4	0.327	14.2	52	5	7	223

(A, Raw sample & B - F, Nano-finished samples with different concentrations)

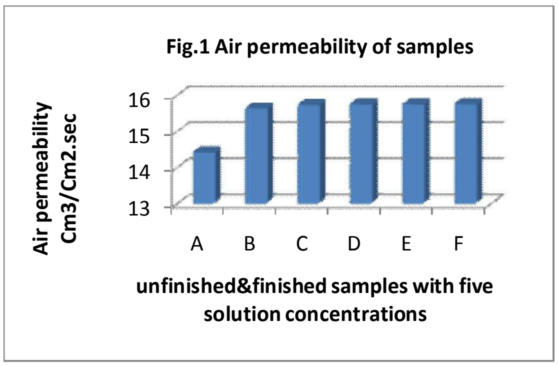
2.3Methods

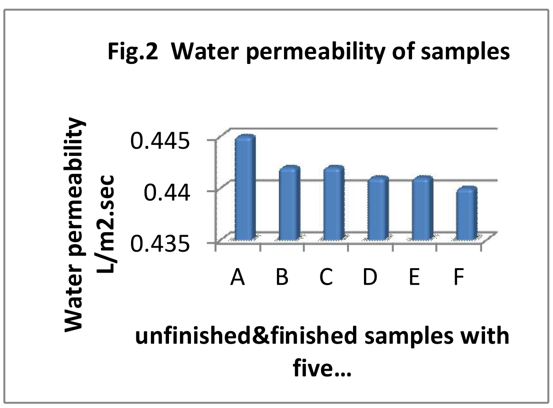
The physical and mechanical properties including air permeability (A.P), water permeability (W.P), water repellency (W.R), bacterial &microbe numbers (B.N), thickness (T), elongation (E), tensile strength (T.S), soil release (S.R), static protection (S.P) and weight (W) have been measured as a testing procedure [17].

3. Results and Discussion

Physical and mechanical properties were tested in this study; Table 2 shows these results.

3.1 Effects of Nano-silver treatment on Physical &Mechanical properties



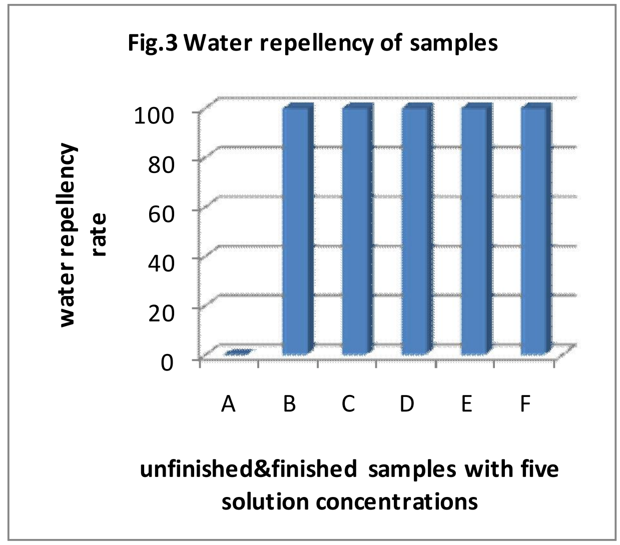


3.1.1 Effects of Nano-Silver Treatment on Air Permeability (AP)

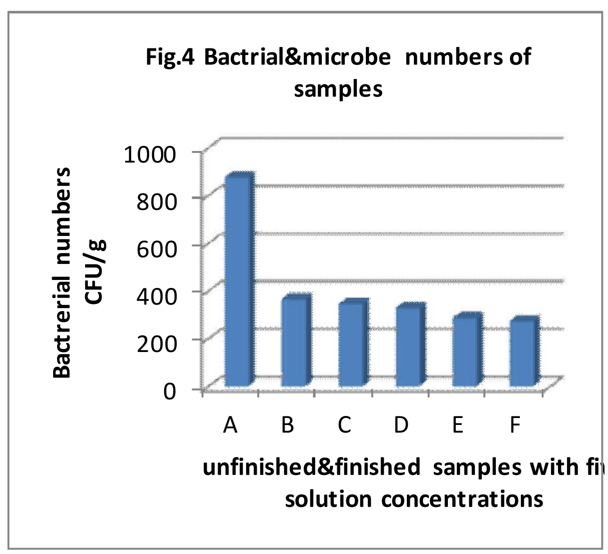
Fig.1 illustrated the results of the air permeability test. It can be clearly seen that there is an increase in the air permeability property by applying Nano-silver finish on the fabric; also a gradual augment has been occurred by increasing the solution concentration. This has been happened due to the use of Twill structure which increased fabric pores. Since the Nano-particles are extremely tiny, increasing the concentration does not have any considerable effect on the air permeability property. Despite Nano film coated the surface and fibers of fabric, air permeability increases after treatment than before treatment this indicates that the breathability improves by Nano treatment.

3.1.2 Effects of Nano-Silver Treatment on Water Permeability (WA)

Fig.2 shows the water permeability of the fabrics. Generally, it can be concluded that water permeability of Nano finished fabrics are lower than the unfinished one. Fabric A had the most water.



Permeability while fabric F had the least water permeability the irregularity caused by the unevenness of finishing process. This can indicate that sweat permeable through fabric to get rid from it, which offers comfort in wearing.



3.1.3 Effects of Nano-Silver Treatment on Water Repellency (WR)

Fig.3 shows that the treatment improves the water-repellent property of fabric. There was completely wetting for whole of upper and lower fabric surfaces before treatment while after treatment there is no sticking or wetting of upper surface. This makes cotton fabric exactly waterproof. This can be attributed to the spaces between the fibers are smaller than the typical drop of water, but still larger than water molecules; water thus remains on the surface of the fabric. However, sweat can still pass through the fabric therefore the performance is permanent while maintaining breathability. **Note:** Water repellency 100 means no sticking or wetting of upper surface. While 0 means complete wetting for whole of upper and lower surfaces[18]

3.1.4 Effects of Nano-Silver Treatment on Bacterial &Microbe numbers (B.N)

Fig.4 shows the comparison between bacterial number before and after Nano treatment. The bacterial and microbe resistance increases after treatment as numbers of bacteria and microbe decreases (there is an inverse relationship between them).

This improvement makes fabric ideal for various applications specially cotton fabric is highly affected with bacteria and microbe in presence of moisture or humidity. The results illustrated that after treatment the increasing on concentration of solution leads to enhance bacteria microbe resistance.

Fig.5Thickness of samples

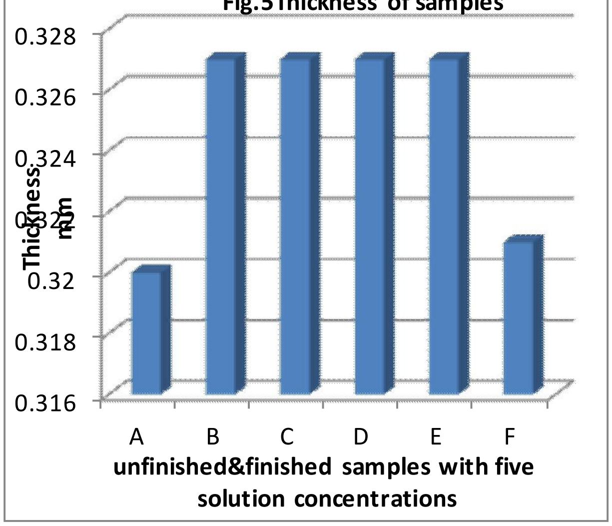
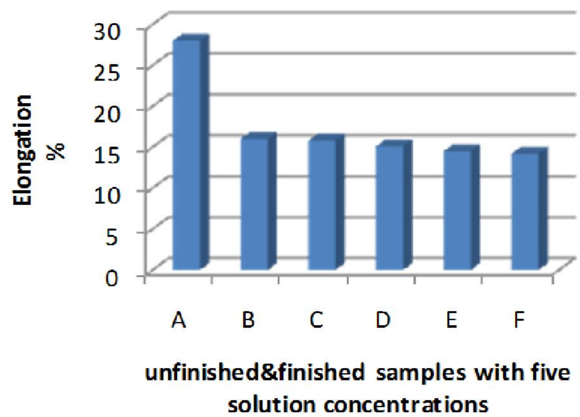


Fig.6 Elongation of samples



3.1.5 Effects of Nano-Silver Treatment on Thickness (T)

Thickness values of the samples are illustrated in fig.5. It is crystal clear that the thickness values of Nano-finished samples are more than the unfinished fabric. More thickness values of the Nano finished fabrics are the result of the yarn swelling phenomena which happens during the finishing process, but by increasing solution concentration to500 PPM a severe fall has been created links decreased.

As shown in table2 and fig.5 thickness after treatment increases a little bit as before treatment this can be referred to the very thin Nano film on the surface and around the fibers. This film is invisible with naked eye as the look and texture of fabric remains.

3.1.6 Effects of Nano-Silver Treatment on Elongation (E)

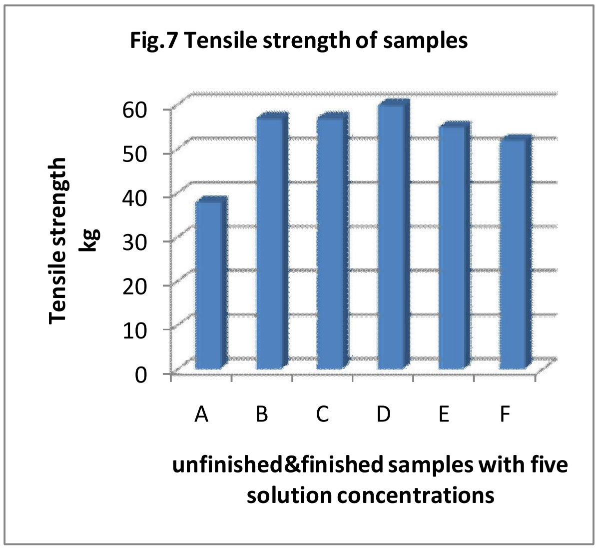
The elongations of samples are presented by fig.6. It can be observed that there are considerable differences in the elongation of fabrics between Nano-finished and unfinished specimens. This essential distinction is due to consolidation of fibers and yarns by the Nano-silver particles.Table2 and fig.6 clarify that fabric elongation decreases after treatment than before treatment this can be attributed to that spaces between fibers after covering with Nano particles decreases, therefore they extensibility decreases.

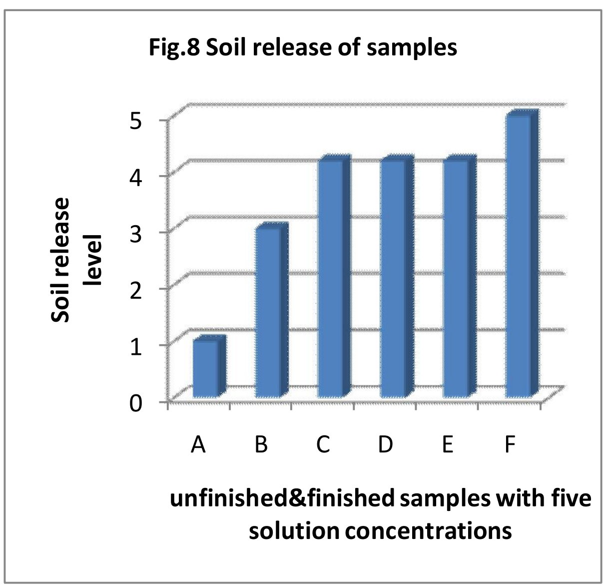
3.1.7 Effects of Nano-Silver Treatment on Tensile Strength (T.S)

Table2 and fig.7 shows that fabric tensile strength increases after treatment than before treatment this can be explained by the Nano particles which coated the fibers and penetrates them, thus make fabric more durable and long lasting.

3.1.8 Effects of Nano-Silver Treatment on Soil Release (S.R)

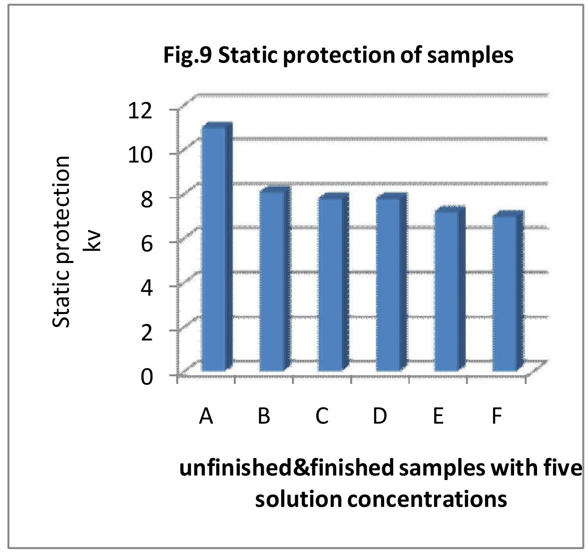
Table 3 and fig.8 shows that fabric before treatment has no soil release while after treatment it prevents soil completely. Protection for textiles against dirt and grease gives an aesthetic appeal which gives an added value. Especially whereas cleaning oily stains from cotton fabrics is very difficult. **Note:** Soil release (oily stain release) evaluated according to AATCC where stain rated on a scale from 5 to 1. As 5 means high soil release while 1means none soil release[19].

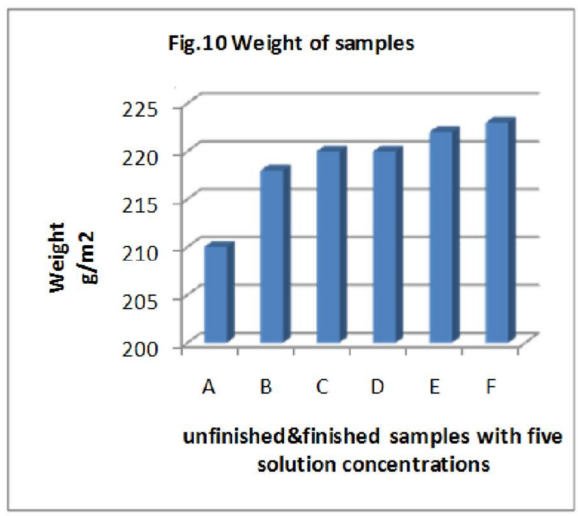




3.1.9 Effects of Nano-Silver Treatment on Static Protection (S.P)

In order to reduce or eliminate buildup of static electricity generally caused by the turboelectric effect. The molecules of an antistatic agent often have both hydrophilic and hydrophobic areas, similar to those of a surfactant; the hydrophobic side interacts with the surface of the material, while the hydrophilic side interacts with the air moisture and binds the water molecules.





As synthetic fibers provide poor anti-static properties, research work concerning the improvement of the anti-static properties of textiles by using nanotechnology has been at large. It was determined that nano-sized particles could impart anti-static properties to synthetic fibers. Such material helps to effectively dissipate the static charge which is accumulated on the fabric. Electrically conductive nano-particles are durably anchored in the fibrils of the membrane of teflon, creating an electrically conductive network that prevents the formation of isolated chargeable areas and voltage peaks commonly found in conventional anti-static materials. This method can overcome the limitation of conventional methods, which is that the anti-static agent is easily washed off after a few laundry cycles. Fig.9 indicates that fabric static protection increases after nano treatment

3.1.10 Effects of Nano-Silver Treatment on Weight (W)

Table2 and fig.10 indicate that fabric weight increases after treatment than before treatment this can be attributed to the nano particles which coated the fibers and penetrates them.

4. Conclusion

Due to medical garments, cotton fabrics may change by the effects of nano-silver finishing on the mechanical and physical properties of them, fabric samples were subjected to the nanosilver finishing process with five different solution concentrations of 100, 200, 300,400 and 500 PPM. The following conclusions have been drawn; nanosilver finishing maximized the air permeability as the used of Twill 1/3 structure while minimized water permeability of the fabric and this can be attributed to the nano-silver particles which fill the fabric pores; water repellency of the nanofinished fabrics was improved because of the generation of links on the fabric by nano-silver particles; Yarn swelling phenomena happens during the finishing process in cotton fabrics which means increment of occupied space by fibers and yarns, and thus rise in the fabric thickness; owing to integration of fibers and yarns by the nano-silver particles, the elongations of fabrics was inclined to applying the nano-silver finishing process, and applying the nanosilver finishing process led to formation of links on the fabric, and consequently tensile strength of the fabrics was increased .After treatment fabric static protection, fabric weight and bactrerial & microbe resistance increased ,as numbers of bacteria and microbe decreases. Ultimately,it was noted that increasing the concentration of the solution to 500 PPM, marked a decline in most of the physical and chemical properties of cotton fabrics.

Corresponding author
F. F. S. Ebrahim
Academy of Specific Studies Nasr City, Cairo, Egypt.
f_wutext@yahoo.com

References

1. Y. Gao and R. Cranston, Recent Advances in Antimicrobial Treatments of Textiles. Textile Research Journal, 2010. 78(1): p. 60-72.
2. D. Hofer, Antimicrobial Textiles—Evaluation of their Effectiveness and Safety in “Bio functional Textiles and the Skin”, Hipler, U. C., and Elsner, P. (eds), Karger,Basel, 2006. 42–50.
3. R. Dastjerdi and M. Montazer, A review on the application of inorganic nanostructured materials in the modification of textiles: Focus on anti-microbial properties. Colloids and Surfaces B: Bio interfaces, 2010.79: p.5–18.
4. Hebeish, M. A. Ramadan, M. E. El-Naggar, M. H. El-Rafie, Rendering cotton fabrics antibacterial using silver nanoparticles– based finishing formulation. Research Journal of Textiles &Apparel (Accepted for publication), 2009.
5. Hebeish, M. H. El-Rafie, M. A. Ramadan, and M. E. El-Naggar, Investigation into the synthesis and characterization of silver nanoparticles. Research Journal of Textiles & Apparel (accepted for publication) 2009.
6. T. L. Vigo, Protection of Textiles from Biological Attack, In “Functional Finishes, Part A, Chemical Processing of Fibres and Fabrics, Handbook of Fiber Science and Technology, 1983. II” Sello, S. B. (Ed.), Marcel Dekker, Inc., New York,: p.367–426.
7. R. Purwar and M. Joshi, Recent Developments in Antimicrobial Finishing of Textiles – A review. AATCC Rev., 2004. 4: p. 22–26.
8. T. L. Vigo, Protection of Textiles from Biological Attack, In “Functional Finishes, Part A, Chemical Processing of Fibres and Fabrics, Handbook of Fiber Science and Technology, 1983. II” Sello, S. B. (Ed.), Marcel Dekker, Inc., New York, p. 367–426.
9. Dring, Anti-microbial, Rotproofing and Hygiene Finishes. In “Textile Finishing”, Heywood, D. (Ed.), Society of Dyers and Colourists, Bradford, 2003 p. 351–371.
10. Y. Gao and R. Cranston, Recent Advances in Antimicrobial Treatments of Textile. Text.Res. J., 2008. 78: p. 60–72.
11. Mahltig and H. Bottcher, Modified silica sol coatings for water-repellent textiles.Journal of Sol-Gel Science and Technology, 2003. 27(1): p. 43-52.
12. Simoncic and B. Tomsic, Structures of Novel Antimicrobial Agents for Textiles – A Review. Textile Research Journal, 2010. 0(0): p. 1-17.
13. Faiza F. S. Ebrahim& Olfat S. M. Mansour Using of Nanotechnology to Reduce the Electrostatic Charges in Saudi men's Robe in Taif Governor– Journal of American Science 2013;9(4).
14. Yadav, A., et al., Functional finishing in cotton fabrics using zinc oxid nanoparticles. Bull. Mat. Sci., 2006, 29(6), 641-645.
15. Hwang, J., J. Muth, and T. Ghosh, Electrical and mechanical properties of carbon-blackfilled,electrospun nanocomposite fiber webs. Journal of Applied Polymer Science, 2007.104(4): p. 2410-2417.
16. Rebecca Kasemeyer, (2007), Disposable dresses: throw-away design from the 1960s, http://textilecollection. wisc.edu. Accessed 16/05/2012.
17. Nahid Ansari, Vajihe Maleki, Principles and Theories Of Physical Testing Of Fibers, Yarns and Fabrics, Jihad Amirkabir University Publication Center, Iran, 2007, 159-218.
18. AATCC 22-92: Method of test for determination of water repellency.
19. AATCC130-2010: Method of test for Determination of Soil Release.

11/9/2014