Marmara Journal of Pure and Applied Sciences 2015, Special Issue-1: 11-15
DOI:10.7240/mufbed.126628

Efficiency of Nano QACs Antibacterial Treated Garments

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ABSTRACT

Growth of bacteria on textiles possesses a range of unwanted negative effects; initially irritation and up to reach eczema, these are concerning the wearer, particularly, if grown bacteria are into socks or underwear; also clothes can generate unpleasant odour, stains and discoloration in the fabric, as well as reduction in fabric strength and subsequently contamination. In the medical field, incorporating bacteria within nursing gowns can be fatal. Aim of this paper, is to assess the functional efficiency of nano-quaternary ammonium compounds (QACs) treated garments; including woven nursing gowns, knitted under-wears and socks. Methodology was undertaken using a number of nine different clothing materials; both woven and knitted garments, with fibre content of 100% cotton, PES/cotton and 100%PES. All of which were treated using nano-QACs antibacterial substance. Both treated and untreated garments were examined using a number of test methods; first, the agar diffusion plate, second, thermo-physiological comfort properties of wettability and heat-loss, finally, spray test was done evaluating stain resistance of nursing gowns.

Keywords: Nano QACs, antibacterial, thermo-physiological comfort.

I. INTRODUCTION

The term "nano" in Greek language means dwarf, materials of nano-scale keep their strength, hardness or flexibility but weight becomes nil [1]. Nano-particles science is concerned by those particles between 1 and 100 nanometres (nm); as the behaviour of those particles dramatically differ from the properties of their macro-scale particles of the same material [2]. One micron is equal 10-6 of a meter; while nanometre nm is equivalent to 10-9 of a meter. Nano-technology depends on the fact of creating structures by moving atoms individually by means of new technology.

The growth of microorganisms on textiles inflicts a range of unwanted effects not only on the garment itself but also on the wearer. These effects include the generation of unpleasant odour, stains and discoloration in the fabric, a reduction in fabric mechanical strength and an increase possibly of contamination [3, 4]. Types of bacteria might subsist within clothing items causing skin infection are Streptococcus Gram-positive, Staphylococcus aureus Gram-positive, Escherichia coli Gram-negative bacilli and Pseudomonas Gram-negative bacilli [5, 6]. The photo below demonstrates a sample for the presence of Cocci clusters in contaminated underwear; mostly observed in women and children.

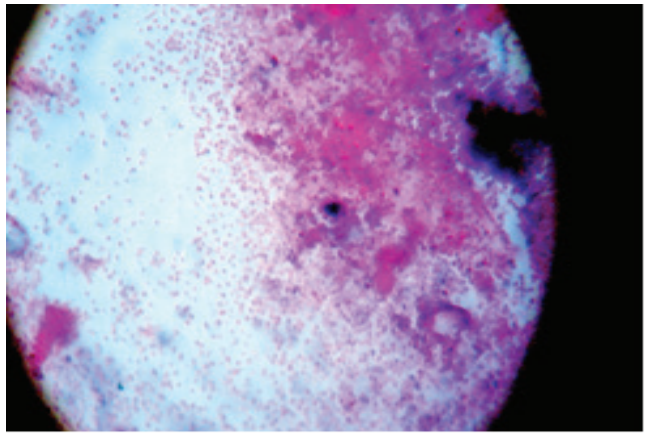

Figure 1. Microscopic figure of Cocci clusters within contaminated underwear.

Quaternary ammonium compounds QAC anti-bacterial treatments are a chemical class of cationic surface active agents [7, 8]. For antimicrobial textile treatments, mainly are compounds of long linear alkyl (12-18 carbon atoms) ammonium groups [8, 9]. Scientific literature of QAC in textiles is limited; QAC consumption is very little in overall products, but in terms of textiles Silane –QAC (Si-QAC) is

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Submitted: 15 October 2014, **Revised:** 04 March 2015, **Accepted:** 01 July 2015

consumed in a larger scale than Ag [8]. Si-QAC is a linear alkyl ammonium; synthetic organic compounds. QAC has been used for decades to disinfect environmental surfaces, as in clinical settings. This is due to the inherent advantage of QAC, against a broad activity spectrum of Gram-negative ad Gram-positive bacteria, in addition to effectiveness over a wide pH range [10].

From a previous study [11] provided new membranes for textiles to enhance personal protection and better meet the competing needs for thermal comfort and protection from liquid penetration by challenges such as blood-borne pathogens and pesticides in protective clothing for occupations where resistance to liquid penetration is needed, such as medical care and chemical workers [2]; from this the present research focus on functional properties of nano-quaternary ammonium compounds (QACs) treated garments; including woven nursing gowns, knitted underwear and socks.

II. METHODOLOGY

Methodology was undertaken using a number of nine different clothing materials; both woven and knitted garments, with fibre content of 100% cotton, PES/cotton and 100%PES. All of which were treated using nano Silane QAC (Si-QAC) antibacterial substance contains 1% Active 3-(trihydroxysilyl) propyldimethyl octadecyl ammonium chloride, with chemical formula C26H58CINO3Si, product of Biosafe Inc. of USA, of 20nm particles. Treatment has been applied on the National Research Centre of Egypt, Nano-particles laboratory, by spraying face and back of garments, while oven curing each side for a specified period of time. In detail, treatment was done into conditioning atmosphere of 21 C and 65% RH, first, all samples were washed using 5g/l detergent at 90 C for 20mins, to get rid of any unwanted residues. Second, samples were rinsed and left horizontally to dry into oven at 200 C for 10mins, making sure that samples have no humidity and to accept nano-treatment. Third, anti-bacterial treatment of nano-quaternary ammonium compounds (QACs) were used to cover both face and back of all samples. Fourth, treated samples are kept for 15mins to absorb all treating substance; then dried into oven at 180 C for a period of 5mins. Finally, samples were kept for 24 hours into the conditioning atmosphere, subsequently rinsed and left to dry horizontally.

Both treated and untreated garments were examined using a number of test methods; first, the agar diffusion plate, determining antibacterial behaviour using BS EN ISO 20645:2004, this was done before and after 10 washing cycles using home laundering process, intended for Staphylococcus aureus bacteria and Escherichia coli (E. Coli) bacteria. Second, thermo-physiological comfort properties were examined, including wettability BS 5445 for sensible perspiration “sweat”, while heat-loss using the temperature gradient was tested as an important aspect for underwear and socks items performance. Third, Spray test using BS EN 2490 (ISO 4920) evaluating stain retardant effect on nursing gowns.

III. RESULTS AND DISCUSSION

3.1. Physical Properties

The physical properties of the tested samples are given in Table1.

Specifications of tested fabrics

F1N	Cotton 100%	WP: 26 WF: 17	Plain 1/1	0.80	0.80	0.250	0.288
F2N	PES/cotton 65%/35%	WP: 19 WF: 32	Twill 2/1	2.76	2.83	0.570	0.570
F3N	PES 100%	WP: 24 WF: 24	Plain 1/1	1.52	1.55	0.350	0.390
F4UW	Cotton 100%	C: 13 W: 15	Knitted-Single jersey	1.38	1.38	0.572	0.482
F5UW	PES/cotton 65%/35%	C: 22 W: 17	Knitted-Single jersey	1.47	1.53	0.542	0.544
F6UW	PES 100%	C: 12 W: 15	Knitted-Single jersey	1.41	1.43	0.500	0.534
F7S	Cotton 100%	C: 15 W: 9	Knitted-Rib	3.14	3.13	1.228	1.228
F8S	PES/cotton 65%/35%	C: 9, W: 9	Knitted-Rib	2.89	2.89	1.242	1.188
F9S	PES 100%	C: 10, W: 8	Knitted-Rib	2.07	2.07	1.420	1.400

Note: N denotes to nursing coats, UW means underwear garments and S is for socks tested items. PES is for polyester. C means course while W is wales in cm^2.

Physical properties of thickness mm and weight g/m^2 showed almost no difference between QAC treated and untreated garments, this is shown in table1; a maximum increase of 0.1g/m^2 in weight within all tested fabrics, when applying the QAC treatment. Limited increase of about 0.03mm in thickness after QAC application shown in F1N, F3N & F6UW; while two other knitted fabrics showed decrease in thickness, these are F4UW & F8S the reason should go to being knitted garments, where irregularity tends to give variations within resultant thickness, the QAC treatment should not be the reason as both mentioned fabrics got exactly the same weight before and after treatment.

3.2. First the Anti-Bacterial Test (Agar Diffusion Plate) For Nursing Gowns, Underwear and Socks

Inhibition zone diameter in mm/1cm sample is shown in Figure 2.a, of untreated Un, treated T and after 10 washing cycles W for all tested garments; woven nursing gown, knitted underwear & knitted socks. Presence of Escherichia coli bacteria and Staphylococcus aureus bacteria are denoted in Figures 2.a & 2.b respectively; all untreated garments did not show any inhibition zone, there is not any bacterial protection, by turn unhygienic for such areas within human body.

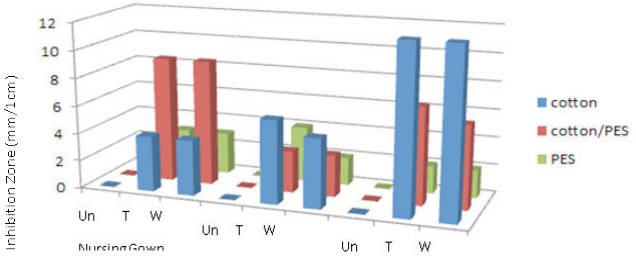


Figure 2.a. Effect of Anti-bacterial treatment on E.Coli Bacteria Inhibition zone

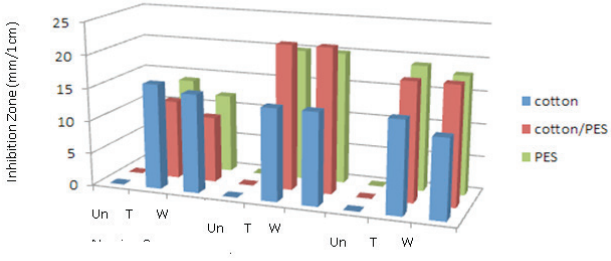


Figure 2.b. Effect of Anti-bacterial treatment on Staphylococcus Bacteria Inhibition zone

QAC anti-bacterial treatment increased intensely inhibition zone by ten to twenty times against E.coli and Staphylococcus aureus; this almost did not vary after ten washing cycles where inhibition zone diameter decreased by a maximum of 2mm/1cm. Fibre content and being woven or knitted fabric did not demonstrate any significant influence in bacterial inhibition zone.

3.3. Second Thermo-Physiological Comfort Properties of Knitted Underwear and Socks

Functional properties of comfort and stain retardant are shown in Figures 3, 4 and 5. For comfort properties of knitted underwear and socks, results of both heat-loss and wettability were obtained. Figures 3.a & 3.b show heat-loss values after 1hour and 30mins of knitted underwear and socks.

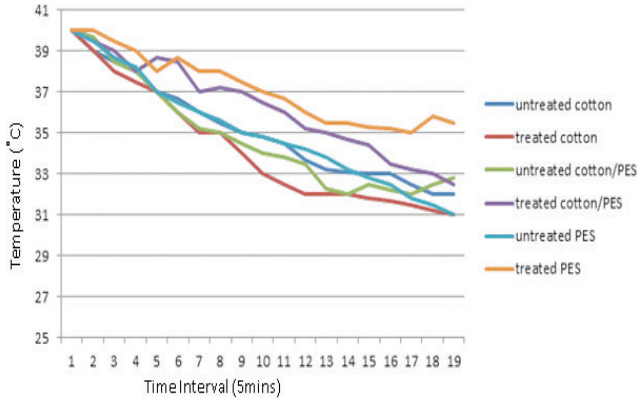


Figure 3.a. Effect of Anti-bacterial Treatment on Knitted Underwear

In general, both underwear and socks garments tested, into this study, did not show any significant correlation between nano-QACs treated and untreated garments, this is clear from Figures 2.a& 2.b. Treated PES (polyester) showed the least heat-loss with 35.5 C after the specified test time, in underwear, this is in line with the nature of polyester as a 100% man-made polymer. Followed by treated cotton/PES and the highest heat-loss was for treated cotton underwear, shown in Figure 2.a. Even though cotton percentage was higher in blended cotton/PES, from Table 1, densely knitted fabric helped the blended underwear keeping body temperature higher than that of cotton underwear; this is shown as yarn density (course and wales/cm2) of cotton/PES.

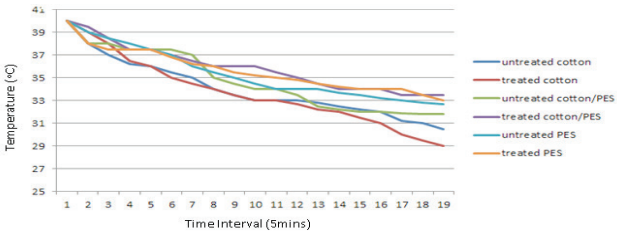


Figure 3.b. Effect of Anti-bacterial Treatment on Heat-loss of Knitted Socks

From this it is better using treated cotton underwear as body temperature should be cooler, if worn in humid warm weather and at the same time effective in terms of anti-bacterial treatment.

Similarly Figure 1.b, both QAC treated PES and cotton/PES socks showed almost the least heat-loss, at about 33 C, while QAC treated cotton socks observed as the highest heat-loss at 29 C. This time the main reason for cotton/PES goes back to the polymer nature as that of PES. In terms of QAC treated knitted garments the best heat loss results were for 100% cotton garments followed by cotton/PES and the worst which should keep body and feet overheated is the QAC 100% PES.

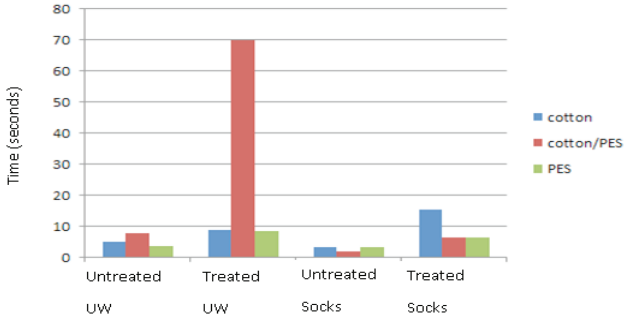


Figure 4. Effect of Anti-bacterial treatment on Wettability of Underwear & Socks

Time in seconds of Wettability for QAC treated garments increased in both cases Underwear and socks. In Figure 3 for underwear, cotton/polyester fabric decreased its wettability, so that the fabric almost became not-wettable, this prevents the underwear from taking away sensible perspiration, leaving human body wet; which should lead to uncomfortable feeling of wearer for such a piece of clothes. This is due to clusters of nanoparticles within course and wales showed, in Table 1, by the increase in thickness by 0.07mm of that particular knitted garment.

From Figure 3, nano-QAC anti-bacterial treatment showed twice the time in seconds for the drop of water to be totally absorbed by the tested socks. The 100% cotton socks demonstrated 4times the amount of seconds needed for the water droplet to be absorbed.

For nano-QAC anti-bacterial treatment, both underwear and socks, the wettability decreased by taking twice the time needed for untreated ones; this was even more for the Cotton/PES underwear and 100% cotton socks. In general, nano-QAC antibacterial treatment decreased human comfort in terms of absorbing moisture. From Table 1 the more yarn density (course and wales/cm^2) of natural fibre content, either cotton or cotton/PES can lead to double the time needed for the water droplet to be absorbed, where cotton fibrils might have played the role of preventing the nano-QAC treatment from being deeply embedded to the inside of the garments, and by turn increased time taken by water droplet to the inside of knitted nano-QAC treated garments. From that it is recommended to spray on nanoparticles while knitted garment of natural fibre content is stretched longitudinally in the wales direction; allowing nanoparticles to immerse within the depth of knits as well as the surface of course.

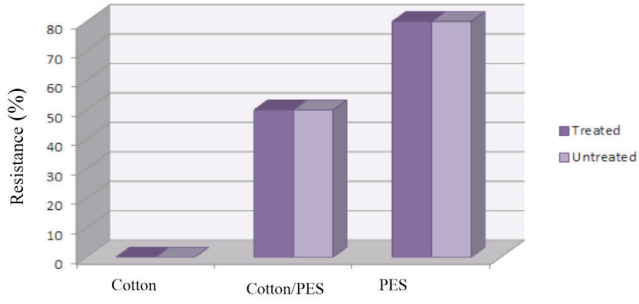
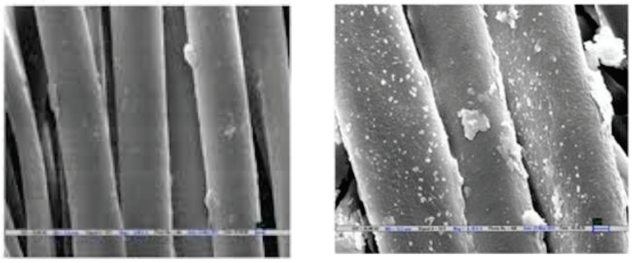


Figure 5. Water resistance performance of untreated and treated samples

3.4. Third Spray Test of Woven Nursing Gowns

Both nano-QAC antibacterial treated and untreated woven nursing gowns, all cotton, cotton/PES and PES showed the same water retardant performance (Figure 5), before and after application of anti-bacterial treatment, this is shown in Figure 6. In general, woven PES fibre content played the key role in resisting water by 80%, which should be strongly recommended either QAC-treated or untreated for nursing

gowns, as it would prevent nursing gowns from dangerous stains, such as blood giving more protection from fatal diseases, bearing in mind the viscosity differences between blood and water droplets of spray test. The percentage of either 100% cotton or blended stopped nursing gowns from repelling water and will easily stain.



Before

After

Si-QAC Treatment of Cotton/PES Woven Nursing Gowns

Figure 6. Fibre surface before and after application of anti-bacterial treatment

IV. CONCLUSION

QAC anti-bacterial treatment increased from ten to twenty times against E.coli and Staphylococcus aureus; this almost did not vary after ten washing cycles.

Functional properties of comfort and stain retardant were almost the same, before and after nano-QAC treatment; the main difference was into the 100%PES under-wear, where nano-QAC treatment decreased heatloss by 4 C, keeping a sort of uncomfortable feeling to wearer. For nano-QAC anti-bacterial treatment, both underwear and socks, the wettability decreased by taking twice the time needed for untreated ones; this was even more for the Cotton/PES underwear and 100% cotton socks. In general, nano-QAC antibacterial treatment of knitted garments decreased human comfort in relation to absorbing sensible-perspiration. On the other hand, for woven nursing gowns both QAC anti-bacterial treatment did not affect stain resistance, where on spray test both treated and untreated garments showed exactly the same results. The higher cotton content fibre within woven nursing gowns the less stain retardant it showed; the best nursing gowns either nano-QAC antibacterial treated or untreated were the 100% PES followed by cotton/PES.

REFERENCES

[1] Black, D.B. Textiles, the Quarterly Magazine of the Textile Institute, N0.1, p. 21-24 (2006).

[2] Environmental protection unit (2014) Module 3: characteristics of particles particle size categories, USA.URL//:ep.gov/apti/bces/module3/category/category.htm,19/9/2014.

[3] Purwar, R. and Joshi, M., Recent Developments in Antimicrobial, Finishing of Textiles—A Review, AATCC Review, 4, 22–26 (2004).

[4] Gao Y. and Cranston R. (2008): Recent Advances in Antimicrobial Treatments of Textiles, Textile Research Journal, 78 (60), 2008.

[5] Gorensek, M. and Recelj, P. (2007): "Nanosilver Functionalized Cotton fabric", Textile Research Journal, Vol. 77(3), pp. 138-141, 2007.

[6] Gabr, B.G., (2010), "Antibacterial Treatments Onto Clothing Items", Melliand International, November, 2010.

[7] Simoncic, B. and Tomsic, B. (2010): "structures of novel antimicrobial agents for textiles – a review, Textile Research Journal, 2010, 80, pp 1721-37.

[8] Windler, L., Height, M. and Nowack, B. (2013): "Comparative Evaluation of Antimicrobials for Textile Application", Environment International, 53 (2013), pp 62-73.

[9] Purwar, R. and Joshi, M. (2004): "Recent Developments in antimicrobial finishings of Textiles – a review, AATCC Rev 2004, 4, pp 22-6.

[10] Messoud, M., Chadeau, E., Chaudouet, P., Oulahal, N. and Langlet, M. (2014): "Quarternary Ammonium-based composite particles for antibacterial finishing of cotton-based textiles", JMST, 2014, 30 (1), pp 19-29.

[11] Obendorf, K. and Sun, G. (2007): "Development of antimicrobial membrane for protective clothing", \\ ntc \project: C05-CR01, Cornell University, National Textile Center Annual Report, USA, November 2007