A New, Durable Antimicrobial Finish for Textiles

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Abstract

AEM 5700 Antimicrobial (3-trimeth-oxysilylpropyldimethyloctadecyl ammonium chloride)+ imparts a durable, antimicrobial finish to textiles. The finish protects the fabric against bacteria and fungi, which cause deterioration. It also inhibits the growth of odor-causing bacteria in *in vitro* tests. *In vivo* organoleptic tests confirm the practicality of this concept under actual use conditions on socks.

Introduction

The need to preserve fabrics against rotting and mildew stain, particularly in industrial usage, has long been recognized. However, the use of biostats to inhibit odor development resulting from biological growth on textiles exposed to perspiration had not been considered a real need until relatively recently. The greater use of synthetic fibers and blends in such items as shirts, hosiery, blouses, and underwear has accelerated the need for bacteriostatic finishes on clothing. The moisture-transport characteristics of such blends tend to cause a greater degree of "perspiration wetness" than occurs with fibers of wholly natural fibers[1]. Additionally, there is a growing volume of literature demonstrating the survival and growth of microorganisms in textiles and their dissemination as a health risk[2,3,4,5]

While several bacteriostatic textile finishes already exist for personal wear, their use for this purpose has not gained ready acceptance. Poor activity against mold and mildew, lack of wash durability, inadequate safety data to meet current requirements, or a combination of these factors has hampered their use. Consequently, a safe, wash-resistant textile finish capable of inhibiting the growth of both bacteria and fungi is required.

For several decades, alkoxysilanes have been widely used by a variety of industries as coupling agents to bind and reinforce substrates. E. Plueddemann[6] has reviewed their use for such purposes. M.Latlief et al. have described the bacteriostatic action of quaternary ammonium compounds on textiles[7,8,9]. The latter compounds exert their influence external to the microorganisms by disruption of the delicate cell membranes and therefore do not need to be absorbed in solution to produce their bacterial killing. The combination of these technologies (that is, the bonding power of alkoxysilanes and the bactericidal power of "quats" on a substrate such as textiles) should result in a durable, safe, antibacterial treatment and does so with AEM 5700 Antimicrobial (3-trimethoxysilylproply-loctadecyl ammonium chloride). An unexpected benefit to the binding of this organosilicon quaternary to a wide variety of substrates is the great increase in spectrum of both antibacterial and fungal killing power[10].

This report describes the practical utility of AEM 5700 Antimicrobial on BIOGUARD®** socks as a representative textile. Laboratory studies were conducted to measure the effectiveness of socks commercially treated with AEM 5700 Antimicrobial against odor-causing bacteria isolated from the foot. In-use clinicals were also conducted to measure actual reduction in foot odor on textiles treated with AEM 5700 Antimicrobial.

Note: Since publication of this article, Dow Corning Corporation's antimicrobial business has been purchased by ÆGIS Environments of Midland, MI. Product nomenclature in this article has been changed to conform with current product names.

I. *In Vitro* Microbiological Studies

The normal bacteria found on the skin of humans are capable of producing characteristic foul odors, especially on the foot and in the axillary region[1,11]. In order to obtain a sampling of normal bacteria on the foot, untreated 75 percent ORLON®++/25 percent nylon socks were worn by laboratory personnel during a routine workday, removed at home, sealed in plastic bags, and returned to the microbiology lab the following day. The bacteria were extracted from the socks in a liquid growth medium, isolated, and identified. The bacterial isolates obtained in the study are listed in Table I.

The bacteria represent a spectrum of Gram positive and Gram-negative organisms capable of producing odors on textiles in contact with the skin. Figure I show the correlation of increase in odor with increase in bacterial isolates.

Once the odor-causing bacteria were isolated, it was necessary to determine if treatment with AEM 5700 Antimicrobial would inhibit the growth of these microorganisms on the socks. ORLON/nylon socks treated with AEM 5700 were supplied by Burlington Socks/Adler*. The socks were tested against each of the bacterial isolates from the foot according to AATCC Test Method 100-1977 [12] modified to include 0.1 percent triton X-100 in a saline inoculum. The results of this testing are in Table II.

The socks treated with AEM 5700 were effective in inhibiting the growth of the odor-causing bacteria on the sock.

A biostatic finish on a textile such as a sock must be durable to repeated home laundering if the benefit of the treatment is to be realized for the life of the article. Table III shows the antimicrobial activity of BIOGUARD socks following repeated laundering.

The antimicrobial applied to the socks was durable for 10 laundering cycles in the detergents tested.

The *in vitro* tests indicated that the socks treated with AEM 5700 Antimicrobial do have a durable antimicrobial finish. To study the practicality of inhibiting the growth of odor-causing bacteria on socks under actual use conditions, an *in vivo* organoleptic test was completed.

TABLE I: BACTERIA ISOLATED FROM WORN UNTREATED SOCKS

Lab Identification Number	Gram Stain	Identification
I	Positive	*Micrococcus sp.*
II	Positive	*Staph epidermidis*
III	Negative	*Enterobacter aglormerans*
IV	Negative	*Acinetobacter calcoaceticus*
V	Negative	*Enterobacter aglomerans*
VI	Positive	*Micrococcus sp.*
VII	Positive	*Micrococcus sp.*
VIII	Positive	*Staph aureus (pigmented)*
XI	Positive	*Staph aureus (nonpigmented)*

TABLE II: ANTIMICROBIAL TESTING OF BIOGUARD SOCKS AGAINST BACTERIA ISOLATED FROM SOCKS

	Organism	%Bacterial Reduction[1]
I	*Micrococcus sp.*	99
II	*Staph epidermidis*	96
III	*Enterobacter aglomerans*	90
IV	*Acinetobacter calcoaceticus*	99
V	*Enterobacter aglomerans*	99
VI	*Micrococcus sp.*	100
VII	*Micrococcus sp.*	99
VIII	*Staph aureus (pigmented)*	99
IX	*Staph aureus (nonpigmented)*	99

[1]*Pecent bacterial reduction as measured against an untreated control sock.*

TABLE III: DURABILITY OF LAUNDERED BIOGUARD SOCKS

Number of Wash Cycles	% Bacterial Reduction[1]
0	97.9
1	98.5
20	99.7
34	90.4
40	98.1

TABLE IV: ANTIMICROBIAL ACTIVITY OF LAUNDERED BIOGUARD SOCKS USING VARIOUS DETERGENTS

Detergent	% Bacterial Reduction[1]
Water Only	99.6
Tide	99.2
Arm and Hammer	98.9
Dynamo	98.6
Cheer	99.2

[1]***Percent bacterial reduction as measured against an untreated control sock.***

II. *In Vivo* Organoleptic Evaluation

Burlington Socks/Adler supplied untreated ORLON/nylon control socks and socks treated with AEM 5700 Antimicrobial to an independent test laboratory* to compare the odors of socks following normal wear by male panelists. The socks included unwashed and washed (ten laundry cycles) control and treated socks.

The male panelists were each given a control and treated sock daily during the test period. Each sock was to be worn on a specific foot. At the end of a workday, panelists reported to the lab to remove the socks, seal them in plastic bags, and receive socks for the next day. Odor evaluations were made by four odor judges 14 hour after removal of the socks on each test day. Individual scoring sheets were used by the judges and new sheets were used everyday of the evaluation. The odor grading scale was 0 to 10 ("no odor" to "very intense and disagreeable odor").

Two-day average odor scores were use to compare unwashed treated and control socks to washed treated and control socks. The Wilcoxon matched pairs test indicated that there was no difference in odor scores between the unwashed treated and control socks at the 95 percent confidence level.

There was a significant reduction in odor of washed treated socks compared to washed control socks at the 99% significance level. The difference in results between washed and unwashed treated socks when compared to controls is explained by the presence of nonsubstantive process chemical such as dye carriers, softeners and wetting agents which are removed upon washing. The presence of these chemicals may:

1) Impart a hydrophobic character to the socks which inhibit intimate contact of microorganisms with the textile surface, thus reducing effectiveness.
2) Impart a pleasant, new-clothing odor which can mask unpleasant odors and is similar in action to a deodorant.
3) Impart a temporary, leachable antimicrobial activity, usually due to the quaternary nature of most textile finishes such as softeners and antistats.

The results of this comparative evaluation show that the ÆGIS antimicrobial agent is bonded to the textile (sock) and is not removed by repeated laundering. In contrast to untreated controls, repeated washing does not destroy the antimicrobial activity nor odor reduction of the treated socks.

III. Application of AEM 5700 Antimicrobial to Other Textiles

Microbiological evaluations have been completed on a variety of other textiles treated with AEM 5700 Antimicrobial such as those listed in Table V.

The fabrics include a diverse spectrum of fiber types and blends. They were treated against a broad spectrum of microorganisms including odor-causing bacteria, and bacteria and fungi which cause rot and mildew. In all cases, the treated textiles exhibited inhibition of growth of the microorganisms on the fabric, thus preventing rot and mildew, and reducing the production of foul odors.

TABLE V: TEXTILES TREATED WITH AEM5700 ANTIMICROBIAL

- Cotton/Polyester Sheeting
- Outerwear Fabrics
- Nylon
- Mattress Ticking
- Carpeting and Throw Rugs
- Underwear
- Hosiery
- Filter Fabrics

Conclusion

Chemical bonding of an organosilicon quaternary ammonium compound to textile substrates results in effective reduction of odor-causing microorganisms under actual in-use conditions of wear. Effectiveness is not reduced by laundering.

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References

[1]Radford, P.J., *American Dyestuff Reporter*, November 1973, p.48-59.

[2]Anderson, K.F., and Sheppard, R.W., *Lancet*, Vol. 1, 1959, p.514-515.

[3]McNeil, E., and Greenstein, M., *Chemical Specialties Manufacturing Association Proceedings*, 1961, p. 134-141.

[4]Mcneil, E., *Developments in Industrial Microbiology*, Vol. 5, 1964, p. 30-35.

[5]Wiksell, J.C., Pickett, M.S., and Hartman, P.A., *Applied Microbiology*, Vol. 25, 1973, p. 431-435.

[6]Plueddemann, E.P., *Journal of Adhesion*, Vol. 2, 1970, p. 184-201.

[7]Latlief, M.A., Goldsmith, M.T., Friedl, J. L. and Stuart, L.S., *Journal of Pediatrics*, Vol. 39, 1951, p. 730-737.

[8]Latlief, M.A., Goldsmith, M.T., Friedl, J. L. and Stuart, L.S., *Journal of Pediatrics*, Vol. 40, 1952, p. 324-329.

[9]Latlief, M.A., Goldsmith, M.T., Friedl, J. L. and Stuart, L.S., *Journal of Pediatrics*, Vol. 40, 1952 p. 599-605.

[10]Isquith, A.J., Abbott, E.A., and Walters, P.A., *Applied Microbiology*, Vol. 24, 1972, p. 859-863.

[11]Tachibaba, D.K., *Annual Reviews of Microbiology*, Vol. 30, 1976, p. 351-375.

[12]*Technical Manual of The American Association of Textile Chemists and Colorists*, Vol. 53, 1977.

FIGURE I: CORRELATION OF INCREASE IN ODOR WITH INCREASE IN BACTERIAL ISOLATES

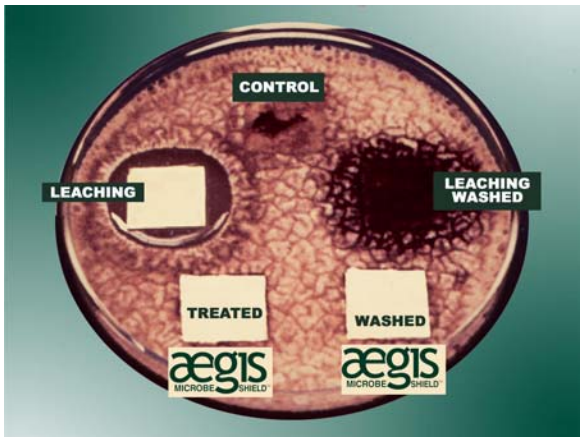

Figure 2
Results: AATCC Method 30; AEM 5700 Treatment, conventional antimicrobial treatment, and untreated control. Washed[1] and unwashed.

Figure 3
Dow Corning 5700 Antimicrobial Agent, applied to fiber (magnified 20 times), prevents Formation of microorganisms that cause odor and discoloration.

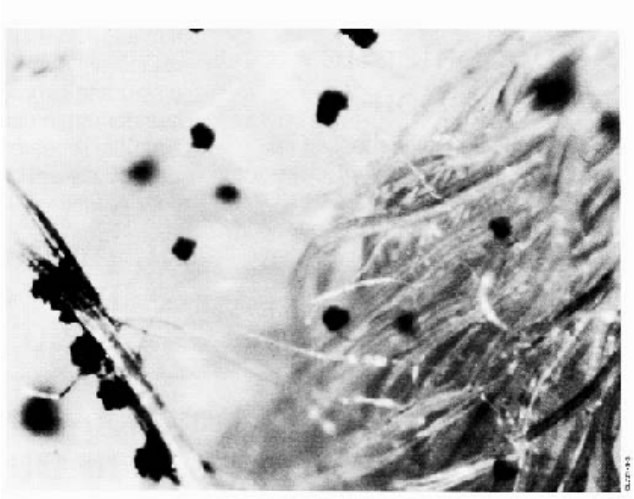

Figure 4
Untreated fiber reveals an unpleasant breeding ground for fungi and bacteria which cause odor problems and deterioration.