How Antimicrobial Treatment Can Improve Nonwovens

By
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Introduction

We can safely say that microbial problems associated with nonwovens can be found in all segments of the nonwovens industry. Problems range from control of germs on surgical nonwoven fabrics, to control of microbial levels on wet wipes, filters, towels, baby diapers, and apparel fabrics. Problems show up in the form of degradation, defacement, odor, and health related problems. The need for controlling these problems, we can report, is evident in both the disposable and nondisposable segments. Proper control of microbial levels is important to the safety and market acceptance of the finished product.

There are to be sure numerous ways to attack microbially related problems. Many times the problem can be eliminated by proper choice of fabric composition. Also, the use of sterilization procedures and barrier packaging has been widely employed to minimize microbial contamination. However, when these methods have not been appropriate, treatment of the fabric with an antimicrobial agent is an approach that has proven successful.

Antimicrobials, we should note, can increase the value and performance of nonwovens, but inherent with antimicrobials are a variety of risks. Risks include environmental and mammalian toxicological concerns, need for broad-spectrum antimicrobial activity, and the need for minimizing microbial adaptation.

There are primarily two major classifications of antimicrobial agents available to the nonwovens industry. These include either the nonleachable or leachable types. Leachable antimicrobial agents are not chemically bonded with the fabric and can be removed by contact with moisture. This paper describes the unique nonleachable Sylgard (now known as the ÆGIS Microbe Shield) treatment technology, its performance characteristics, safety, appropriate mill application techniques, current uses, and its potential utility on the full spectrum of nonwoven products.

Treatment

The active ingredient of ÆGIS Microbe Shield™ treatment, as we describe, is 3-trimethoxysilylpropyldimethyloctadecyl ammonium chloride. The ÆGIS Microbe Shield is a safe, broad spectrum, durable, nonleachable antimicrobial treatment. Data generated on nonwoven fabrics show that the product will control the growth of bacteria, fungi, yeasts, and algae on a treated surface. The organosilane referred to as AEM 5700™ offers safety and efficacy advantages not found with traditional leaching types of antimicrobials.

Durability

Durability of an antimicrobial used in nonwovens is desirable for at least two reasons, as we will demonstrate. The first of these reasons would be to provide antimicrobial protection through an extended period of time. Many nonwovens have a long service life or are expected to function in conditions of high moisture. Value is added to these nonwoven materials if the negative effects of microorganisms can be minimized.

The second reason is one of safety to man and the environment. In applications such as surgical drapes, it must be assured that materials coming from the drape do not cause cytotoxicity or other negative effects on the patient. In other applications effects on normal skin microbial flora and the skin irritating, sensitizing, or absorptive properties of the antimicrobial must be considered. The ultimate fate of the nonwoven goods and any environmental impact also needs to be understood. The value of a bound antimicrobial is certainly understandable as one considers the above statements.

The ÆGIS Microbe Shield treatment is certainly durable and resistant to repeated washing, contact with body fluids, and abrasion. This durability exists because of the unique organosilane technology that utilizes two diverse technologies. The trimethoxysilyl functionality of the molecule has the ability to bond covalently to a variety of receptive surfaces. The octadecylammonium chloride portion of the molecule offers ionic bonding capacity and the antimicrobial activity. A variety of previously reported practical "real world" tests have been run to confirm the durability of this unique technology. [1,2]

Antimicrobial Activity

To show the value of controlling microorganisms on nonwovens using the ÆGIS Microbe Shield treatment a variety of tests have been conducted. Tests include work significant to all components of the nonwovens industry (Table I). Although AEM 5700 is not an efficient solution active antimicrobial, the obligatory Minimum Inhibitory Concentration (MIC) tests have been run. Results of these tests show clearly the broad-spectrum activity of the AEM 5700.

The relevance of MIC data to use on fabrics is said to be hard to interpolate, so additional studies were done using AATCC-100 Antimicrobials On Fabrics Test (Table II). The broad-spectrum antibacterial and antiyeast nature of AEM 5700 when bound to textiles is clearly demonstrated. An extension of this test was done by American Converters. Documentation of their work was done using Scanning Electron Microscopy. The hollow appearance of the test organisms on the treated nonwoven surface after 15 minutes of exposure show clearly their nonviable condition.

Many nonwovens, it is said, are subject to attack by defacing and deteriorating fungal attack. The relationship of allergenic response to fungal spores can also be linked to contaminated surfaces. Data here show clearly the variety of fungi that can be controlled by AEM 5700 treated fabrics.

Using classical laboratory microorganisms provides valuable data, but does not project to the real world conditions of a hospital, a diaper, or our homes. To more closely simulate real world conditions, a modification of the AATCC-100 Antimicrobials On Fabrics Test was run. This test essentially utilized a series of clinical isolates rather than laboratory organisms. Results are clear in that control of these organisms was conclusively demonstrated (Table IV).

To further extend the database on the antimicrobial activity of AEM 5700 treated nonwovens, a series of tests were taken to understand performance in medical/surgical applications. Body fluids, such as human sweat, defibrillated blood, whole blood, and irrigation fluids were tested. A microbial load was added to each of the test fluids and then aliquots were applied to treated and control fabrics. Results were very uniform and confirm that microbial loads from such fluids are readily controlled on AEM 5700 treated surfaces (Table V).

Nonwovens treated with an antimicrobial agent are often expected to perform in ambient conditions, according to the authors. The traditional unbound types of antimicrobials must have significant amounts of water present for them to manifest their antimicrobial activity. A test was undertaken where treated and untreated samples were randomly placed in several environments. Retrievals show +95% reductions in micro flora on the treated surfaces.

To demonstrate the actual reduction of microorganisms during surgical procedures, American Converters has been conducting a study at Northwestern University. An Iso•BAC® surgical drape was prepared with treated and untreated areas within the fenestration. Retrievals were done after each surgical procedure. At this point in the study, 98 surgical procedures have been monitored. Differences between the retrieved micro flora on treated and untreated areas have been consistently over 99%.

Adaptation Study

It has been observed in the Dow Corning laboratory that many traditional leaching types of antimicrobial agents are susceptible to inductive or mutative adaptation. Adaptation is a phenomenon whereby a cell adjusts enzymatically (inductive) or genetically (mutational) to a toxicant in its environment. A study was undertaken with AEM 5700 treated surfaces to determine the potential adaptation of Gram (-) and Gram (+) organisms after contact exposure. No increase in adaptive potential was noted after five successive exposures. This indicates an extremely low potential for adaptation (Table VI).

Environmental safety testing results reveal:

1. Low Solution Activity - AEM 5700 antimicrobial agent is designed to exhibit its maximum antimicrobial activity only when chemically bonded to a surface. Therefore it is not very effective just diluted in water.
2. Reactivity to Surfaces - The chemistry of AEM 5700 antimicrobial agent is such that it rapidly exhausts from water solutions onto any solid material present in the system. This means that little if any waste material remains.
3. Non-Leaching Character - Once AEM-5700 antimicrobial agent has come in contact with a surface, chemical changes occur which prevent it from being subsequently removed. Therefore, the material remains on the substrate and does not enter the environment.

In the industrial processes where AEM 5700 antimicrobial agent is used, essentially all of the material is applied to the substrate, thus minimizing concerns about waste streams. Data have been generated showing that small amounts of the material, if present in normal plant waste streams, will *not* affect typical waste treatment facilities or wildlife. If unexpected releases or spills occur, there are simple procedures for neutralizing the microbiological activity of AEM 5700 antimicrobial agent to further reduce any potential problems.

The ÆGIS Microbe Shield treatment of nonwovens is said to be possible at almost every stage in the manufacturing process. Application methods have included padding, spray and foam finishing. Treatment is best carried out from a water solution of the product. Upon removal of the water, the nonvolatile silane forms covalent bonds with the fabric surface and itself, resulting in excellent durability. Processing temperatures up to 160 degrees centigrade have shown little effect on performance or degradation of the antimicrobial finish.

We can accurately report that treatment of fibers or web prior to nonwoven processing is possible. However, post treatment as the final finishing step has been the preferred site for the treatment. Treatment levels vary from 0.1% to 1.0% active ingredient depending upon the type of fabric and performance characteristics required.

In processing it is also said to be possible to add the treatment along with other finishing chemicals such as water repellents, binders, hydrophilic treatments, etc. Ionic character is an important consideration due the cationic nature of the AEM 5700. Antimicrobial performance and efficiency of treatment will vary depending on the chemical nature of the mixtures. Optimization of addition point and addition levels is critical to insuring the least expensive and most efficacious treatment possible.

Many nonwoven fabrics are very useful where microbial odors are a significant nuisance. Our experience with the reduction of microbial odors on woven fabrics has been through laboratory and odor panel testing.[3] The extension of this work was done with nonwovens. Typical diaper constructions were treated and put in capped jars. *Proteus mirabilis* and a small amount of artificial urine nutrient were added. Ammonia measurements were taken using Gastec® tubes. Results show clearly the value of the ÆGIS Microbe Shield treatment in the reduction of microbial odors (Table VII).

Many applications for nonwovens undoubtedly demand that the service life of the fabric be extremely long. Deteriorative effects of microorganisms can shorten this product life. In other applications value is lost because of defacement by fungi. To demonstrate the effectiveness of the ÆGIS Microbe Shield treatment in reducing bacterial and fungal deterioration and defacement, classical burial tests were run.

During filtration processes filter media are susceptible to the fouling and deteriorative effects of microorganisms. Filter media can also act as a reservoir for organisms whose presence on waste products can have negative effects on the filtrate. The polyester fiberfill used to filter the fish tank water was treated and untreated. The untreated control tank is totally fouled with algae, whereas the tank with the AEM 5700 treated fiberfill is still clear.

Safety and toxicity testing requirements for nonwoven fabrics are said to vary, depending on the end application. Mammalian toxicity testing of AEM 5700 has centered on satisfying the safety requirements for use in medical applications. Over thirty separate safety studies have been generated using AEM 5700 and AEM 5700 treated substrates. Tests range from mutagenicity, teratogenicity and cytotoxicity tests to routine LD50, irritation, and sensitization tests. A percutaneous absorption test further supports the safe use of AEM 5700 treated materials by showing that no material was absorbed into the test animals. This eliminates any concerns for applications where intimate skin contact is expected.

Antimicrobials as pesticides, are highly regulated by Federal and State laws. The ÆGIS Microbe Shield treatment, based on AEM 5700 antimicrobial agent, has been approved by the U.S. Environmental Protection Agency (EPA) for nonwoven applications including baby diapers, mattress pads, and industrial nonwovens. The product is also listed with the U.S. Food and Drug Administration (FDA) for treatment of orthopaedic softgoods and surgical nonwovens.

Applications

All of the above data, we should indicate, were generated by Dow Corning Corporation and cooperative partners such as Burlington Industries and American Converters (now Baxter Healthcare). This has led us to a variety of applications where the value and performance of nonwovens is being enhanced by the use of the ÆGIS Microbe Shield treatment. Some specific applications include:

- ***Baby Diapers/Adult Incontinence Pads:*** Laboratory studies conducted on nonwoven cover stock and treated baby diapers show that the ÆGIS Microbe Shield can minimize odor associated with microbial breakdown of urine (Table VII). The treatment has also proven to be effective in control of microorganisms associated with yeast infections and diaper rash.

  Treatment of the diaper or incontinence pads results in a more hygienic product for the consumer. Market studies have been conducted (and recent products launched[4]) which shows that consumers perceive more value in treated products.

  The data presented in Tables IV and VII show significant odor reduction in diapers and reduction of microorganism levels in adult incontinence pads when AEM 5700-treated.

- ***Surgical/Medical Medical Nonwovens***: Clinical studies have shown that nonwoven fabrics are superior to woven fabrics in control of postoperative infections.[5] These findings have led to major acceptance of nonwovens in the health care industry. In the U.S.A. a variety of the surgical nonwovens being produced are antimicrobial agents treated to provide an even greater reduction of risk of postoperative infection. Products being marketed include surgical drapes, instrument wraps, Mayo stand covers, and surgical packs. Products with the added antimicrobial treatment are finding excellent acceptance by the medical community.

Data generated on the AEM 5700 antimicrobial agent treated fabrics show that microorganisms, which contact the surface, are rapidly killed. The data presented in Table IV show the difference in the control of a variety of medically significant microorganisms when tested on AEM 5700 treated and untreated control fabric.

In the surgical arena, contact of the treated nonwoven with body and irrigation fluids is a frequent occurrence. Studies conducted (Table V) show that the AEM 5700 treated surface maintains antimicrobial activity against potentially pathogenic microorganisms in the presence of body and irrigation fluids.

Microorganism growth in ambient humidity conditions has been demonstrated on a variety of nonwoven surfaces. Rate of growth is dependent on the nature of the fabric and its pattern of storage and use. Ongoing tests show significant reduction in microorganism levels on treated surfaces when compared to controls. The significance of these data to the use of instrument wraps and other medical packaging is readily understood. The value of this to more diverse applications such as food packaging has yet to be evaluated.

In the hospital environment concerns relating to adaptation of microorganisms to antimicrobial agents have resulted in routine changes in sanitizer/disinfectant agents by the infection control staff. This is done to reduce the potential for adaptation. Fabrics treated with AEM 5700 have not shown the potential for adaptation (Table VI).

Added performance and value have also been shown on AEM 5700 treated bandages, sponges, surgical masks, and gowns. Benefits of reduced infectious organisms and a more hygienic surface are clearly realized.

- ***Mattress Pad****:* Microbial odors are associated with mattress pads as a result of the degradation of perspiration, dead skin and organic matter. These problems are persistent because laundering of the mattress pad is done less frequently than the sheeting or other bedding materials. The major organisms associated with mattress pads are the fungal organisms, but bacteria may cause problems under special conditions.

  Several manufacturers are now offering AEM 5700 treated mattress pads to both the residential and commercial markets. Commercial markets in the United States have expanded due to recent state laws requiring that hotels and motels have mattress pads on beds.

  Composition of the mattress pads consists of a mixture of woven and nonwoven fabrics. Testing both the nonwoven and woven fabrics is required to ensure performance and wash durability.

- ***Filtration****:* Filtration media have been found to foul as a result of microbial slimes coating the surface causing a reduction of filtration capacity, we have noted. Filtrate quality can also be negatively affected by the presence of microorganisms on the filter media. Swimming pool and aquarium filters can be plugged by large amounts of algae or bacteria. Treatment of the filter media with AEM 5700 antimicrobial agent has been found to both preserve the life of the filter media and purify the filtrate. Degrees of effectiveness vary considerably depending on the substrate and the fluids being filtered. Efficacy can be obtained as shown in Figure 4 where an aquarium with treated filter floss is compared to one with an untreated filter floss.

Notice that the treated floss has no effect on the sensitive fish population in the aquarium.

Although results with aquarium treatment are on a small scale, data would indicate that larger scale water purification is possible. Evaluation of this technology to filtration of metalworking fluids, cosmetics, paints and foods is currently in progress.

- ***Civil Engineering****:* Proper design and choice of materials, we can state, have minimized the effects of microorganisms in most civil engineering applications. In most cases a variety of polypropylene fabrics are available for applications including roadbed stabilization, drainage ditch liners, pond liners and erosion control. Actual microbial degradation of the polypropylene fabrics is minimal. Yet, microorganisms (bacteria and fungi) have been shown to live on the surface of these materials and could affect water transport and/or degrade susceptible binders. Work with AEM 5700 has demonstrated its reactivity to such surfaces. Soil burial tests using nonpolypropylene nonwovens shows clearly the value of the ÆGIS Microbe Shield treatment at reducing degradation of such fabrics.

  The potential to improve value and performance of nonwovens used in civil engineering applications has been demonstrated but reduction to "real world" practice has not yet been done.

Summary

Increasing the value and performance of nonwovens is entirely feasible by incorporating the ÆGIS Microbe Shield (formerly known as Sylgard) to control microbially related problems. Fabrics, which have been treated, are more hygienically suitable for surgical/medical uses, diapers, filters, etc., due to the durable, broad-spectrum antimicrobial activity, and safety of the antimicrobial treatment. Control of deterioration and defacement and elimination of microbially related odors has been found to enhance the value and performance of both disposable and nondisposable nonwoven products.

Efforts continue, we can say, to expand the use of the ÆGIS Microbe Shield Program to areas such as food packaging, civil engineering and textile fabrics where control of microbially related problems is important in the end application.

References

1) Gettings, R.L. and Triplett, B.L., “A New Durable Antimicrobial Finish For Textiles,” Book of Papers*, AATCC National Conference*, 1978.
2) White, W.C., McGee, J.B., and Malek, J.R., “New Antimicrobial Treatment For Carpet Applications,” *American Dyestuff Reporter*, June 1983.
3) Editors – “Antimicrobial Finishes On Fabrics,” *Evaluation of AATCC Technical Manual*.
4) Editors – “Fungicides, Evaluation On Textiles: Mildew and Rot Resistance of Textiles,” *AATCC Technical Manual*.
5) Moylan, J.A. and Kennedy, B.V., “Wound Infections – Are There Controllable Factors?” *8th Annual INDA Technical Symposium*, 1980.

Table I - Results

Minimum Inhibitory Concentration Test AEM 5700 Antimicrobial

Test Organism	*MIC*[1]
Streptococcus faecalis - Gram (+) Bacteria	10
Escherichia coli - Gram (-) Bacteria	100
Pseudomonas aeruginose - Gram (-) Bacteria	100
Aspirgillus niger – Fungus	1000
1. M*icrograms per milliliter*	

Table II - Results

AATCC Method 100, Antimicrobials on Fabrics
AEM 5700 Antimicrobial Treated Nonwovens

Sample	*Microorganism*	*% Reduction*
Untreated Control	*Staphylococcus aureus* Gram (+) Bacteria	16
AEM 5700 Treated	*Staphylococcus aureus* Gram (+) Bacteria	100
Untreated Control	*Escherichia coli* Gram (-) Bacteria	0
AEM 5700 Treated	*Escherichia coli* Gram (-) Bacteria	99.6
Untreated Control	*Klebsiella pneumoniae* Gram (-) Bacteria	0
AEM 5700 Treated	*Klebsiella pneumoniae* Gram (-) Bacteria	99.9
Untreated Control	*Pseudomonas aeruginosa* Gram (-) Bacteria	0
AEM 5700 Treated	*Pseudomonas aeruginosa* Gram (-) Bacteria	98.6
Untreated Control	*Saccharomyces cerevisiae*, Yeast	0
AEM 5700 Treated	*Saccharomyces cerevisiae*, Yeast	100
Untreated Control	*Candida albicans*, Yeast	0
AEM 5700 Treated	*Candida albicans*, Yeast	99.9

Table III - Results

AATCC Method 30 Fungicides Evaluation on Textiles
AEM 5700 Antimicrobial Treated Nonwovens

	Percent Covered		
Sample	*In 3 Days*	*In 5 Days*	*In 7 Days*
Untreated	20	60	100
Treated, Level A	0	5	20
Treated, Level C	0	0	0
1. *Aspergillus Niger*			

Table IV – Results

Clinical Isolate Control
AEM 5700 Antimicrobial Treated Goods

Sample	*Microorganism*	*% Reduction*
Untreated Control	*Citerobacter diversus*, Wound Isolate	14.3
AEM 5700 Treated	*Citerobacter diversus*, Wound Isolate	93.6
Innoculum	*Citerobacter diversus*, Wound Isolate	0
Untreated Control	*Pseudomonas aeruginosa*, Urine Isolate	28.3
AEM 5700 Treated	*Pseudomonas aeruginosa*, Urine Isolate	99.9
Innoculum	*Pseudomonas aeruginosa*, Urine Isolate	0
Untreated Control	*Staphylococcus aureus*, Wound Isolate	0
AEM 5700 Treated	*Staphylococcus aureus*, Wound Isolate	99.7
Innoculum	*Staphylococcus aureus*, Wound Isolate	0
Untreated Control	*Escherichia coli*, Urine Isolate	11.6
AEM 5700 Treated	*Escherichia coli*, Urine Isolate	98.6
Innoculum	*Escherichia coli*, Urine Isolate	0
Untreated Control	*Proteuse mirabilis*, Wound Isolate	0
AEM 5700 Treated	*Proteuse mirabilis*, Wound Isolate	99.5
Innoculum	*Proteuse mirabilis*, Wound Isolate	0

Table V – Results

Fluid Compatibility Tests
AEM 5700 Antimicrobial Treated ISO•BAC Fabric

	Percent Reduction[1] with 15 Minute Contact		
Sample	*Buffered Phosphate*	*Saline*	*Serum*
Untreated Linen	8	0	0
Untreated Nonwoven	0	0	0
Treated Nonwoven	99+	90+	90+

1. *Klebsiella pneumoniae*

Table VI - Results

Bacterial Adaptation Studies
AEM 5700 Treated Fabrics

	Percent Reduction[1]				
Sample	*In 1 Day*	*In 2 Days*	*In 3 Days*	*In 4 Days*	*In 5 Days*
Untreated Exposed[1]	0	0	0	0	0
Treated Exposed[1]	99+	99+	99	98	99+
Untreated Exposed[2]	0	0	0	0	0
Treated Exposed[2]	99	98	98	99	99

1. *Klebsiella pneumoniae*
2. *Staphylococcus aureus*

Table VII – Results

Microbially Generated Ammonia Odor Study[1]
AEM 5700 Treated Nonwovens

	Total Ammonia			
Sample	*In 2 Hours[2]*	*In 4 Hours[2]*	*In 6 Hours[2]*	*In 8 Hours[1]*
Untreated	0	0.5	5.5	55.5
Treated Level A	0	0	2	28
Treated Level B	0	0	0.5	3.5

1. *Proteus mirabilis* (clinical) Inoculum: 1,000,000 CFU/ML
2. Parts Per Million