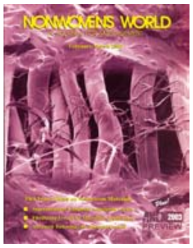

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ADVANCED TECHNOLOGY FOR BACTERIAL CONTROL

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The textile industry is challenged by the presence of microorganisms and the negative effects they cause. Deterioration, defacement and odors are all dramatic effects that occur from the microbial contamination of woven, nonwoven and composite fabrics. Fabrics can also act as a "harbor," as most offer ideal environments for medically significant microorganisms. The ability to make textiles resistant to microbial contamination has advantages in many applications and market segments. This is especially true in medical markets where engineered textiles have already contributed a degree of aseptic sophistication to historically used materials.

Both woven and nonwoven textiles have microbial problems, and their control is a complex chemical, physical and microbiological task. The microbiological integrity of textiles has been the object of numerous studies ranging from the sterilization of nonwovens to the evaluation of the barrier properties of engineered fabrics. Test data generated with nonwovens and engineered fabrics generally support the fact that these materials contribute positively to the reduction of microorganisms.

A wide array of uses has led such materials into end uses where microbiological problems are no longer simply questions of biodeterioration. The problems caused by microorganisms in these uses have extended the needs of antimicrobial treatments to control organisms that cause unsightly staining and odors and to reduce the number of organisms such that the fabrics are not considered harbors or transmission substrates for toxigenic organisms.

In order to understand microorganisms and their impact on woven and nonwoven materials, we must understand the uses and abuses of these materials. Just as the end use is different for each article, the potential for microbial contamination and the ability to control this contamination are very different. Fabrics are designed for specific end uses, and specific antimicrobial agents are added for different end use performances, needs and claims.

MICROORGANISMS

Mold, mildew, fungi, yeast, bacteria, and viruses are part of our everyday lives. The thousands of species of microorganisms that exist are found everywhere in the environment -- including on our garments and on our bodies.

Microorganisms -- their body parts, metabolic products and reproductive parts -- cause multiple problems to building materials and furnishings. They are human irritants, sensitizers and toxic-response agents and cause disease and general discomfort. Clearly, microorganisms are the potent pollutants in the indoor environment, on our clothes and on our furnishings.

Microorganisms need moisture and nutrients, and most need to be associated with a surface. Moisture can come from catastrophic or normal events such as a leaky roof, a sweaty pipe, a leaky radiator, condensation on windows, condensation on more subtle surfaces where dew points are reached, humidified air from the HVAC system or any of hundreds of other sources. Air conditioners, bathrooms, wall-to-wall carpets, draperies, wall coverings, furniture, bedding and ceiling tiles create ideal habitats for microorganisms. Nutrients utilized by microorganisms can be organic material, inorganic material and/or living tissue. For example, bacteria play an ,important role as part of the body's microflora and, along with the skin, are shed continuously. Given acceptable growth conditions, they can multiply from one organism to more than one billion in just 18 hours.

MICROBIAL CONTROL

Medical care facilities, schools, hotels, residences, food storage areas and manufacturing facilities such as electronics, food, pharmaceuticals and other at-risk material production areas need to have a reaction plan for avoidance and control of airborne and surface-sourced microbial contaminants. Strategies for control of microbes must also exist for garments, beddings, linens, wipes, surgical fabrics and other textiles used in everyday life.

The human symptoms of building-sourced microbial exposure involve an array of physical and systemic reactions affecting the skin, mucous membranes, eyes, upper and lower respiratory tracts, and muscles. Some reactions are short-term (acute) and others are long-term (chronic). All affect productivity, health costs and well-being. Similarly, microbes sourced from textile reservoirs can cause these same effects.

ANTIMICROBIALS: WHAT ARE THEY?

The term antimicrobial refers to a broad range of technologies that provide varying degrees of protection for products and buildings against microorganisms. Antimicrobials are very different in their chemical nature, mode of action, impact on people and the environment, in-plant handling characteristics, durability on various substrates, costs and how they interact with good and bad microorganisms.

Antimicrobials are used on textiles to control bacteria, fungi, mold, mildew and algae. This control reduces or eliminates the problems of deterioration, staining, odors and health concerns that they cause.

In the broad array of microorganisms, there are both good and bad types. Antimicrobial strategies for bad organisms must include ensuring that non-target organisms are not affected or that adaptation of microorganisms is not encouraged. Antimicrobials, when properly applied, limit greatly the life habits and environments for the common dust mite.

Microorganisms cause problems with textile raw materials and processing chemicals, wet processes in the mills, roll or bulk goods in storage, finished goods in storage and transport, and goods as they are used by the consumer. These effects are extremely critical to clean room operators, medical facilities and food processing facilities. They are also an annoyance and aesthetic problem to athletes and consumers. The economic impact of microbial contamination is significant, and the consumer interests and demands for protection is at an all- time high.

ANTIMICROBIAL TECHNOLOGIES

Leaching technology. Antimicrobials do not all work the same. The vast majority of antimicrobials work by leaching or moving from the surface on which they are applied. This is the mechanism by which leaching antimicrobials poison a microorganism. Such chemicals have been used for decades in agricultural applications with mixed results. Other than the challenges of limited durability, leaching antimicrobial technologies have the potential to cause a variety of other problems when used in nonwovens. These leaching properties can cause contact with the skin and potentially affect the normal skin bacteria, cross the skin barrier and/or have the potential to cause rashes and other skin irritations. A m0re serious problem with leaching technologies is that they allow for the adaptation of microorganisms.

Bonded antimicrobial technology. An antimicrobial with a unique mode of action that does not leach is a molecularly-bonded technology. The organofunctional silane has a mode of action that relies on the technology remaining affixed to the substrate, killing microorganisms as they contact the surface to which it is applied. Effective levels of this technology do not leach or diminish over time. When applied, the technology actually polymerizes with the substrate, making the surface antimicrobial. This type of antimicrobial technology, effectively used in textiles, is likely to be used in human contact situations or where durability is important. In either case, durability to wear and laundering with broad-spectrum antimicrobial activity have been demonstrated.

Mode of operation. Antimicrobials primarily function in two different ways. Acting as a poison, the conventional leaching types of antimicrobials leave the textile and chemically enter or react with the microorganism. The unconventionally bound antimicrobial stays permanently affixed to the surface and, on a molecular scale, physically stabs (the lipoprotein components of the membrane) and electrocutes (the anionic biochemicals in the membrane) the microorganism on contact to kill it. Like an arrow shot from a bow or bullet shot from a gun, leaching antimicrobials can be effective, but are consumed in the process of working, wasted in random misses or complexed by the use and abuse of other chemicals in the environment. Some companies incorporate leaching technologies into fibers and slow the release rate to extend the useful life of the antimicrobial, even adding chemical binders and claiming they are "bound".

Whether leaching antimicrobials are extruded into the fiber, placed in a binder or simply added as a finish to fabrics or finished goods, they all function the same. In all cases, leaching antimicrobial technologies provide a killing field or "zone of inhibition." This zone exists in real-world uses if it is assumed that the right conditions are present for leaching of a lethal dose at the time that it is needed. The zone of inhibition is the area around the treated substrate onto which the antimicrobial chemistry leaches or moves to, killing or inhibiting microorganisms. This killing or inhibiting action of a leaching antimicrobial is witnessed when an AATCC 147 test or other zone of inhibition tests are run. These tests are used to measure the zone of inhibition and clearly define the area where the antimicrobial has come off the substrate and killed the microorganisms in the agar. As fabrics treated with conventional leaching antimicrobials are washed, treatments are easily removed.

Figure 1 presents a typical zone of inhibition test method. Zone A represents a textile material treated with a leaching antimicrobial. Zone B surrounding the substrate represents the zone of inhibition, and the sublethal zone is shown in Zone C. The area at which zones B and C merge is presented as the zone of adaptation. **Figure** 2 shows the actual difference between the leaching and the non- leaching antimicrobial treatments on textiles, both as first treated and then after five household launderings.

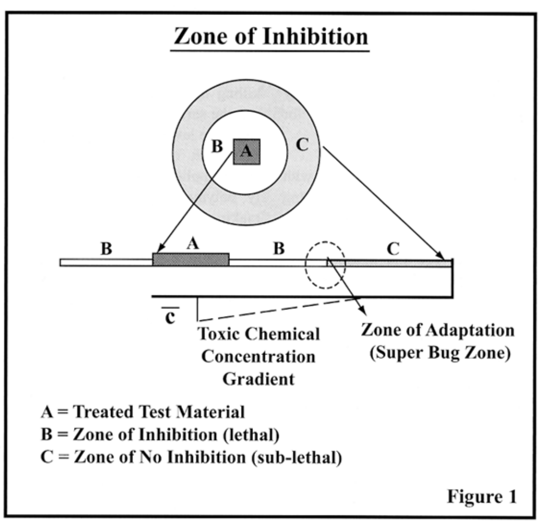

Figure 1

SUPER BUGS

Microbes are living organisms and, like any living organisms, will take extreme measures to survive. Microorganisms can be genetically mutated or enzymatically induced into tougher "super-strains" if they are exposed to sublethal doses of an antimicrobial agent. This ability of microorganisms to adapt to potential toxicants has been recognized in the medical community for years. Sublethal levels of antibiotics are generated in patients who discontinue taking antibiotics once their symptoms subside instead of continuing through to the end of the period prescribed by the physician. The exposure of the microbe to a sublethal dose of an antimicrobial can cause mutation of its genetic materials, allowing for resistance that is then replicated through the reproductive process, creating generations of microorganisms that are no longer affected by the chemistry. This phenomenon is of serious concern to the medical community and food processing industries and should be a serious consideration for the textile industry as it chooses the antimicrobials to which it will be exposing the public and its workers.

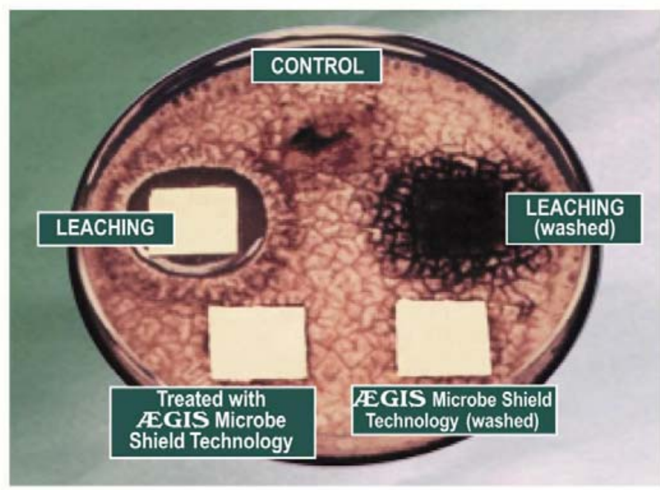

Figure 2

As with any chemistry that migrates from the surface, a leaching antimicrobial is strongest in the reservoir, or at the source, and becomes weaker the farther it travels from the reservoir. The outermost edge of the zone of inhibition is where the sublethal dose can be found. This is known as the zone of adaptation **(Figure 1)**. This is where resistant microbes that have been produced by leaching antimicrobials are found. The ongoing challenge for leaching technologies is the control of the leach rate from their reservoir such that a lethal dose is available at the time that it is needed.

This is demonstrated in Figure 3 from experiments where a microbe sample was taken from the outer edge of the zone of inhibition of a common leaching antimicrobial from treated carpet fiber and used to inoculate a new test plate. This second test plate shows the adapted microorganisms growing within the zone of inhibition. The adapted organism is taken from the second plate and used to inoculate a third plate. The microorganism used to inoculate this plate is fully adapted to the leaching antimicrobial and has overgrown the fabric. The ghost zone indicates the organism being slowed not controlled by the leaching toxicant. All this occurred within just two generations of the test organism under these test conditions.

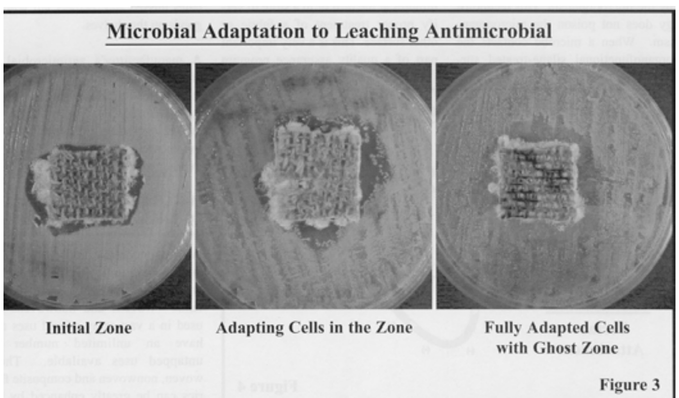

Figure 3

NON-LEACHING ANTIMICROBIAL TECHNOLOGY

A significantly different and much re unique antimicrobial technology used in the nonwovens and building construction industries does not leach, but remains permanently affixed to the surface on which it is applied. Applied in a single stage of the wet finish process, the attachment of this technology to surfaces involves two means. The first, and most important, is a very rapid process, which coats the substrate (fabric, fiber, etc.) with the cationic species (physisorption) one molecule deep. This is an ion exchange process by which the cation of the silane quaternary ammonium compound replaces protons from water or chemicals on the surface. The second mechanism is unique to materials such as silane quaternary ammonium compounds. In this case, the silanol allows for covalent bonding to receptive surfaces to occur (chemisorption). This bonding to the substrate is then made even more durable by the silanol functionality, which enables them to homopolymerize. After they have coated the surface in this manner, they become virtually unremovable, even on surfaces with which they cannot react covalently **(Figure 4)**.

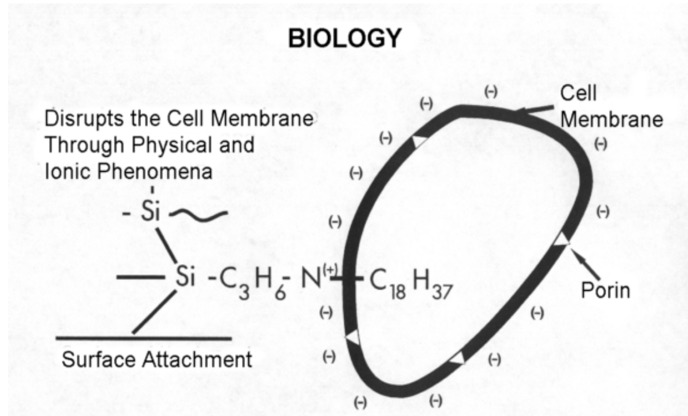

Figure 4

Once polymerized, the treatment does not migrate or create a zone of inhibition, so it does not set up conditions that allow for adapted organisms. Because this technology stays on the substrate, it does not cross the skin barrier, does not affect normal skin bacteria, nor does it cause rashes or skin irritations. This organofunctional silane technology has been used for over two decades to treat surfaces from leather and foams to virtually all types of fabrics and is not consumed by the microorganism. This technology does not poison the microorganism. When a microbe contacts the organofunctional silane-treated surface of the fabric, the cell is physically ruptured by a sword-like action and then electrocuted by a positively charged nitrogen molecule. This antimicrobial technology has been verified by its use in consumer and medical goods including socks, surgical drapes and carpets in the U.S., Asia and other areas of the world. This technology has been used for nearly 25 years without any human health or environmental problems inside manufacturing facilities or in actual end use situations.

ANTIMICROBIAL TREATMENT VERIFICATION

Another important property of a useful antimicrobial is that its presence should be easily verifiable. In effect, this is the only way to know that an antimicrobial is really on the product. There is no easy way to tell whether leaching antimicrobials are present on a product. The only known verification technique for a leaching chemistry is to use exacting laboratory tests, which take days or weeks to perform. With the bound antimicrobial technology though, a simple staining test can be performed in a matter of minutes at the mill or in a store to verify proper treatment of a fabric or other surface. This is a very important part of a quality assurance program that gives manufacturers, retailers and consumers confidence that a feature, normally invisible to the senses, can be seen and is actually on the product providing the protection for which they have paid.

ANTIMICROBIAL REGULATORY AGENCIES

As we've discussed, not all antimicrobials are alike. There are technical differences between antimicrobials that affect their life, performance, verification, safety and costs. However, one thing is true for all antimicrobials and sometimes the treated products as well: the U.S. Environmental Protection Agency, the EEC Biocide Directives and other regulatory agencies around the world regulate all antimicrobials. Antimicrobials must be registered with the EPA, the EU and other regulatory bodies for the specific uses. In some cases, antimicrobials have been misapplied and, in other cases, antimicrobial products have made errant claims resulting in fines, sometimes totaling in the hundreds of thousands of dollars. Products exported to regulated areas with unregistered treatments or errant claims have been turned back, supply dates missed and retailers left. without goods on the shelves.

A manufacturer's antimicrobial of choice should be specifically registered for use on the end product being manufactured, i.e., an antimicrobial that is only U.S. EPA-registered for use in shoes should not be used for treating socks.

MATCHING ANTIMICROBIALS TO END USES

With an understanding of microbial pests and antimicrobial technologies, we can begin to fit solutions to problems. Wovens and nonwovens are used in a vast array of end uses and have an unlimited number of untapped uses available. These woven, nonwoven and composite fabrics can be greatly enhanced by the use of the proper antimicrobial agents.

The many challenges faced in choosing the right antimicrobial technology for the nonwovens, wovens, or composite fabric industry include the following:

Durability. Durable fabrics need durable features. End uses for industrial fabrics engineered for use in medical facilities must have antimicrobial treatments that can survive abrasion, sterilization, wet/dry cycles, freeze/thaw cycles, alcohol rinse and other physical and chemical stresses.

Waste control/toxicity. Antimicrobials control a range of microbial pests, but they must be chosen and engineered so that they do not affect good and helpful microbes. Although heavy metals have long been rejected where they come into contact with the environment or human skin, silver- based products have unexpectedly made a resurgence.

Spectrum of activity. Many materials are antimicrobial at the right concentration, but in healthcare applications, it is very important to have as broad a spectrum of activity as is safe and functional. When integrating antimicrobial treatments into durable goods, this is even more important. A broad spectrum antimicrobial will have activity at the deliverable concentration or contact concentration that kills or inhibits gram-positive bacteria, gram-negative bacteria, yeast and mycelial fungi. Added spectra could include algae, viruses or other microbial pests. More and more often, specialized chemistries have activity against tuberculosis, microbial spores or other pathogenic organisms.

Adaptation. Any soluble agent that affects a microorganism's life has the potential to set up conditions where the microbial cells adapt or mutate to resistant types. This is undesirable in almost all settings, but clearly should not be tolerated in a medical facility. Use of standard disinfectants or sanitizers calls for a rinse after the desired contact time. This is to minimize the risks associated with sub-lethal levels of the antimicrobial being present and risking adaptation or other forms of resistance.

APPLICATIONS

Engineering the right antimicrobial usage requires a thorough understanding of the end use and subsequent use and abuse of the finished goods. In the medical industry, industrial fabrics have both proven and potential use in a wide array of end uses. With the infrastructure in place to design and produce the variety of fabric materials used in industrial fabrics, the industry has the tools and products to fit many needs in the medical marketplace.

Construction materials. Roofing and envelope materials integrated with the engineered textiles can offer installation and performance properties that make them a preferred choice over alternatives. Antimicrobial treatments enhance the value of these products.

Finishing materials. Engineered textiles have a tremendous potential as components of ceiling, wall and flooring structures. Their use as awnings, tarps and tents are well integrated into medical facilities as functional and decorative materials. These aesthetic and functional materials all benefit from antimicrobial treatments.

Furnishing materials. As components of upholstered furniture, bedding or carpeting, engineered fabrics have a unique role to play and strengthen their value with antimicrobial treatments.

Housekeeping goods. From wipes, mops and sponges to other cleaning supplies, engineered fabrics have utility and, with an antimicrobial finish, serve a more durable and functional life.

Garments Engineered textiles bring strength, cleanability, breathability, insulation properties, barrier properties and antimicrobial treatments as valuable assets to many uses. These properties are all important in the great variety of garments used in medical care operations..

Central storeroom materials. Bedcovers, linens, wraps, drapes, covers and other textile or film-like materials can all be made, and made better, with engineered fabrics. The mix and value of properties of nonwoven, woven and composite fabrics are a certain opportunity for engineered fabrics with antimicrobial treatments.

CONCLUSION

The first decade of the twenty-first century brings us to a unique convergence of marketplace needs and microbial control technology that offers effective reduction of bacteria, mold, mildew, yeast and mites on all kinds of nonwovens for the useful life of the products. Nowhere is this more important than in the industrial engineered fabrics industry.

The polls have indicated that the market is ready for antimicrobial products, and the buying public has reinforced the polls with their pocketbooks. More than seven times as many anti-germ products were produced in 1998 than in 1992, and consumers' demands for antimicrobial products have grown dramatically since 1998. The press event nature of sick building syndrome and adapted superbugs has echoed from consumer concern to courtroom and insurance company exclusions. This increased demand for antimicrobial-protected products warrants increased scrutiny of the antimicrobials being put into the products. There are hundreds to thousands of chemistries on the earth that kill microorganisms. Many of these -- like arsenic, lead, tin, mercury, silver, plant extracts and animal extracts -- are natural, but can also be highly toxic to people and the environment. An effective antimicrobial for the textile and construction products industry can't just kill or repel microorganisms, it must do so safely, over the life of the treated product and without negatively affecting the other important characteristics of the textile.

To benefit from the consumer needs and demands for antimicrobial/ antibacterial products, as well as the antimicrobial/antibacterial performance needs of the medical products world, manufacturers have a choice. In choosing, they should utilize a treatment that provides for a microbial control claim and an antimicrobial finish for their textile products consistent with their claims and the needs of their target consumers. This selection should be done by considering the following:

- Adopting a non-leaching antimicrobial that doesn't pose the risk of crossing the skin barrier or negatively affecting the normal microbial flora of the skin. If it creates a zone of inhibition or must integrate into the cell to have function, then it leaches or moves and has the potential to cause problems to people and the environment.
- Adopting an antimicrobial technology with a proven history of use will help shorten the timelines in bringing products with an antibacterial/antifungal/odor-reducing feature to market.
- Adopting a non-leaching antimicrobial that doesn't pose the risk of creating adaptative resistant microorganisms.

- Adopting an antimicrobial technology that is registered with the EPA, the EO and other regulatory agencies for the specific product it is applied to.
- Adopting an antimicrobial technology that can be tested for proper application at the mill or at the retailer's. A verifiable quality assurance program should be a key component of any application process.
- Adopting an antimicrobial technology that has technical and marketing support.

Numerous retail buyers and medical purchasing agents have stated that the antimicrobial/ antibacterial feature is quickly moving to a standard requirement for the products that they buy. Manufacturers that don't currently treat fabrics with a durable antimicrobial finish should consider shielding their products from eroding value by incorporating microbial control. As manufacturers look to enhance the value of their products, they should recognize antimicrobial finishes as a clear way of increasing value and enhancing market positioning.

This is a clear way for the industrial fabrics industry to further enhance the value of its products to the medical industry as it seeks to expand the scope of its business activities.

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