A COMPARISON OF ANTIMICROBIALS FOR THE TEXTILE INDUSTRY

W. Curtis White M.S., ÆGIS Environments, Midland, MI, USA
Robert A. Monticello Ph.D., ÆGIS Environments, Midland, MI, USA
James W. Krueger, ÆGIS Environments, Midland, MI, USA
Patrice Vandendaele, Devan Chemicals, Renaix, Belgium

Abstract

Antimicrobials are used on textiles to control bacteria, fungi, mold, mildew, and algae and 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. Control strategies of the bad organisms must include consideration of being sure that non-target organisms are not affected or that adaptation of microorganisms is not encouraged.

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. This can be extremely critical to a clean room operator, a medical facility, or a food processing facility, or it can be an annoyance and esthetic problem to the athlete or normal consumers. The economic impact of microbial contamination is significant and the consumer interests and demands for protection is at an all time high.

The term antimicrobial refers to a broad range of technologies that can provide varying degrees of protection for textile products 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.

This paper covers the full range of positive effects that antimicrobials bring to the textile industry and provides for a full discussion of the types and properties of antimicrobials.

Introduction

Mold, mildew, fungus, yeast, and bacteria (microorganisms) are part of our everyday lives. There are both good and bad types of microorganisms. The thousands of species of microorganisms that exist are found everywhere in the environment and on our bodies.

These organisms impact producers, retailers, and users of all kinds of products. The scope of this reaches from whole buildings, building materials, people, equipment, processes, production of textiles, storage and transport of textiles, and users of textiles.

Understanding microorganisms, who they are, where they come from, and why they grow on certain materials provides us a basis for controlling them and their negative effects. This control capability, with the right technology, can provide for a valuable feature on a wide range of textiles.

This is a challenging time and an exciting time for the textile industry. In most geographical areas of the world the polymer, fiber, textile, and garment industries are contracting. This contraction from manufacturing exists in an economic and cultural environment where consumers are demanding better products with more features. This means that specifications and quality control criteria are ever more important and features that offer the marketing edge for product differentiation, better margins, maintaining product line or corporate image, and are cost effective have an important place in every companies strategies.

Value enhancing finish technologies can be developed around fads and fashion trends but the most enduring finish technologies are designed to improve fabrice performance and function. Antimicrobial finishes enhance apparel performance while meeting consumer-led feature demands. Antimicrobial treatment is rapidly becoming a standard finish in some textile categories and should be viewed as a finish with a future. This paper discusses why antimicrobial finishes are being applied to more products than ever before, the basic differences between antimicrobial technologies, and what those differences mean in safety, durability, and effectiveness.

Why Antimicrobial Treatment?

A recent CBS News poll showed that three out of four Americans are conscious of germs in their daily lives. This poll indicated that 61 percent of the women surveyed make an extra effort to buy antibacterial or antimicrobial products. Concern over the problems of odor, staining, deterioration, and human health conditions such as allergies or infectious disease are fueled by the daily press events of antibiotic resistant germs, flesh eating bacteria, *E. coli* in food, tainted water, and even "sick building syndrome". Articles in textile trade magazines and the daily press throughout Europe and Asia have reinforced the problems of microorganisms in our daily lives and the desire by the public for safe ways of solving microbial problems. The use of antibacterial soaps have been brought into question and the problems of *Listeria* and *Salmonella* in foods have also made headline news. The year 2000 brings us to a unique convergence of marketplace needs and microbial control technology that offers the useful and emotive reduction of germs, bacteria, mold, mildew and yeast on all kinds of textiles for the useful life of the products.

The polls have indicated 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(1) and consumer's demands for antimicrobial products have grown dramatically since 1998. This increased demand for antimicrobial-protected products warrants increased scrutiny of the antimicrobials being put into the products. There are hundreds and maybe thousands of chemistries on the earth that kill microorganisms. Many of these, like arsenic, lead, tin, mercury, silver, plant extracts, and animals extracts are "natural" but, can also be highly toxic to people and the environment in most uses. An effective antimicrobial for the textile industry can't just kill or repel microorganisms, it must do so safely, over the life of the treated products, and without negatively affecting the other important characteristics of the textile.

Antimicrobial Finishes

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 used by leaching antimicrobials to poison a microorganism. Such chemicals have been used for decades in agricultural applications with mixed results. Besides affecting durability and useful life, leaching technologies have the potential to cause a variety of other problems when used in garments. These include their negative effects because, they can contact the skin and potentially effect the normal skin bacteria, cross the skin barrier, and/or have the potential to cause rashes and other skin irritations. A more serious problem with leaching technologies has to do with their allowing for the adaptation of microorganisms.

An antimicrobial with a completely different mode of action than the leaching technologies is a molecularly bonded unconventional technology. The bound unconventional antimicrobial technology, an 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 is used in textiles that are likely to have human contact or where durability is of value. (3) Dr. M. Bourgeois and researchers at the "Institute Textile de France" in Lyon have accomplished this type of surface modification by electron beam grafting of acrylic monomers with quaternary ammonium compounds to hydroxyl active surfaces. In either case, durability to wear and laundering and broad spectrum antimicrobial activity has been demonstrated.

Antimicrobial Function & Adaptation

Antimicrobials primarily function in two different ways. The conventional leaching types of antimicrobials leave the textile and chemically enter or react with the microorganism acting as a poison. The unconventional bound antimicrobial stays affixed to the textile and, on a molecular scale, physically stabs (the membrane) and electrocutes (the 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 are often effective, but they are used up in the process of working or wasted in random misses. Some companies incorporate leaching technologies into fibers and slow the release rate to extend the useful life of the antimicrobial or even add them to chemical binders and claim they are now "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 exist for leaching of a lethal dose at the time that it is needed. The zone of inhibition is the area around the treated substrate into 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 on inhibition test is run. These tests measure the zone of inhibition created by a leaching antimicrobial and clearly defines the area where the antimicrobial has come off the substrate and killed the microorganisms in the agar. Such a phenomenon can be seen in Figure 1. This Figure shows the difference between the leaching and the non-leaching antimicrobial treatments on textiles both as first treated and then after five household launderings.

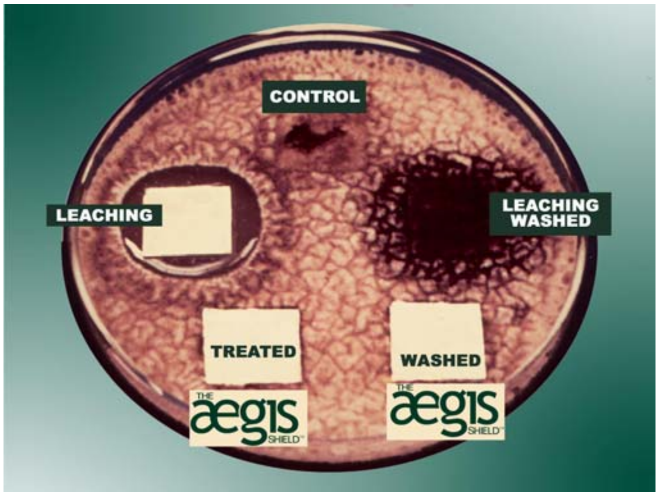

Figure 1

Zone of Inhibition Testing

Microbes are living organisms and like any living organism 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 (exposed to - but not killed) of antimicrobial agents. 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 the 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 their 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 phenomena 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 their workers.

As with any chemistry that migrates from the surface - a leaching antimicrobial is strongest in the reservoir, or at the source, and weakest 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 where resistant microbes are found that have been produced by leaching antimicrobials. This is demonstrated in the following images where a microbe was taken from the outer edge of the zone of inhibition of a common leaching antimicrobial from treated carpet fiber (Figure 2) and used to inoculate a new test plate. This second test plate (Figure 3) 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 (Figure 4). 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 but not controlled by the leaching toxicant. All this occurred within just two generations of the test organism under these test conditions.

Figure 2

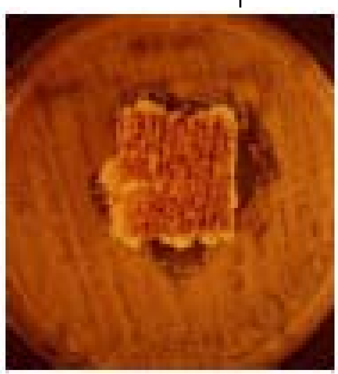

Figure 3

Figure 4

A significantly different and much more unique antimicrobial technology used in the textile industry does not leach but instead remains permanently affixed to the surface it is applied to. Applied in a single stage of the wet finish process, the attachment of this technology to surfaces involves two means. 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 irremovable, even on surfaces with which they cannot react covalently. (2) (Figure 5).

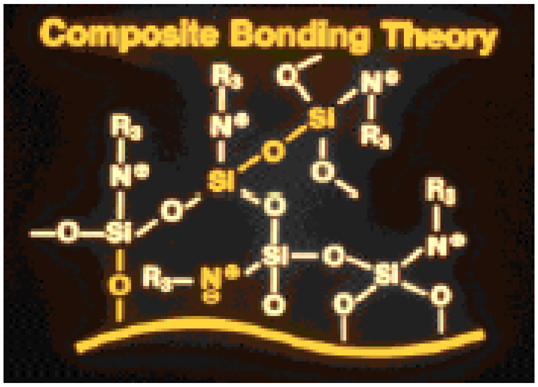

Figure 5

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 the technology stays on the substrate it does not cross the skin barrier and does not effect normal skin bacteria, 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. It does not poison the microorganism. When a microbe contacts the organofunctional silane treated surface of the fabric, the cell is physically ruptured by a swordlike action and then electrocuted by a positively charged nitrogen molecule (Figure 6). This antimicrobial technology has been verified by its use in consumer and medical goods including socks, surgical drapes and carpets in the USA, Asia, and other areas in the world. This technology has been used for nearly twenty-five years without any human health or environmental problems in manufacturing facilities or in actual end use situations.

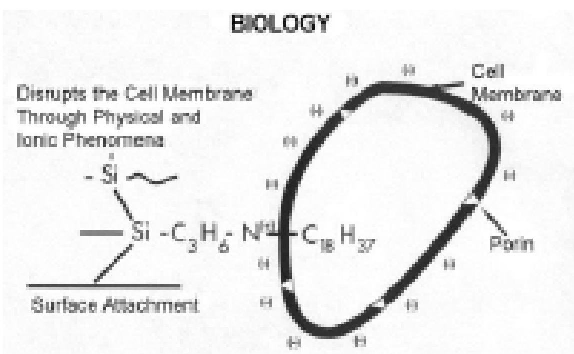

Figure 6

Antimicrobial Treatment Verification

Another important property of a useful antimicrobial is that its presence should be verifiable. In effect, it 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 the manufacturer, the retailer, and the consumer 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 Regulation

As we've discussed, not all antimicrobials are alike. There are technical differences between antimicrobials that affect their life, performance, safety and costs. But, one thing is true for all antimicrobials and sometimes the treated products. All antimicrobials are regulated by the Environmental Protection Agency, the European Union or other regulatory agencies around the world. Antimicrobials must be registered with the EPA, the EU, and other regulatory bodies for the specific uses. In some cases, antimicrobials have been misapplied. In other cases, antimicrobial products have made errant claims resulting in fines, sometimes totaling in the hundreds of thousands of dollars. A manufacturers antimicrobial of choice should be specifically registered for use on the end product being manufactured (i.e., an antimicrobial that is only EPA registered for use in shoes should not be used for treating socks).

Summary

To benefit from the consumer demand for antimicrobial/antibacterial products and for the antibacterial and antifungal performance needs of the textile world, manufacturers have a choice. In choosing, they should utilize a treatment that provides for an odor reduction/antibacterial 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:

- Adopting an antimicrobial technology with a proven history of use. This will help shorten the timelines in bringing products with an antibacterial/antifungal/odor-reducing, antimicrobial feature to market.
- Adopting a non-leaching antimicrobial that doesn't pose the risk of crossing the skin barrier. If it creates a "zone of inhibition" it leaches or moves and has the potential to cause problems.
- 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 EU, and other regulatory agencies for the specific product it is applied to
- Adopting an antimicrobial technology that can have its proper application tested for at the mill or at the retailers. 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 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 feature with a future and the future is now.

References

(1) Marketing Intelligence Service, Ltd., Naples, NY

(2) J.R. Malek and J.L. Speier, Development of an Organosilicone Antimicrobial Agent for the Treatment of Surfaces, Journal Of Coated Fabrics, Vol. 12, p. 38 - 46

(3) Gettings, R. L. and B.L. Triplett. A New Durable Antimicrobial Finish For Textiles. AATCC Book of Papers. 1978. Pg. 259-261.