ANTIMICROBIAL TREATMENTS: SURVIVAL AND EFFECTIVENESS IN THE REAL WORLD OF OUTDOOR PERFORMANCE MATERIALS

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ABSTRACT

"There is hardly any category of products and end uses where the challenge of microbial control is greater than the broad category of outdoor fabrics."

Microorganisms cause numerous problems to outdoor fabrics. Control of these problems can be provided by the wise choice of fabrics and antimicrobial agents. Standards organizations have provided accelerated tests that simulate real-world conditions.

This paper explains the problems associated with microorganisms and the strategies used for antimicrobial protection of outdoor fabrics. Examples of "stress" tests and antimicrobial performance tests are given to illustrate the aesthetic and performance benefits of antimicrobial treatments.

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INTRODUCTION

There is hardly any category of products and end uses where the challenge of microbial control is greater than the broad category of outdoor fabrics. Outdoor performance materials as fabrics, laminates, or coated fabrics are assaulted in many different end-use environments from the staining and deteriorating effects of bacteria, fungi, and algae microorganisms. This includes materials such as tents, covers, signage, underlayments, and many other materials engineered for outdoor performance.

Years ago, the antimicrobials of choice for outdoor performance materials included a wide array of very potent leaching pesticides. These toxicants, for the most part, are no longer available. Whether it was the chlorinated phenols with their real and imagined controversy and problems associated with chlorinated dioxins, or the linkage to the often used heavy metal organometallics and their problems of bioconcentration in the food chain and effects on non-target species, these legacy poison mechanism pesticides are no longer available.

The change of available antimicrobial materials has driven the outdoor performance products industry to newer mechanisms of formulation and delivery of antimicrobials and to whole new modes of action.

An interesting perspective on these new antimicrobial treatment methods and materials is that their use has also driven the change of testing techniques used for screening and product development as well as for end-use performance predictions.

END USE AND ABUSE SPECIFICATIONS

The affect of microorganisms on outdoor performance fabrics is a hot topic in today's marketplace. The ability to control bacteria, fungi, algae, and other microbes on woven, nonwoven, laminated, and coated fabrics can open the doors to marketplace opportunities. Product developers and manufacturers are investigating the use of antimicrobial treatments to meet consumer and end-use demand. Microorganisms associated with outdoor performance fabrics have a negative affect on the integrity and appearance irrespective of the fabric's end-use. They also cause serious product degrading, staining, and deterioration.

Construction textiles, for example, can be key factors in indoor environmental quality. Virtually any housewrap, insulation, sealant, soil stabilizer, and exterior or interior treatment, can create significant microbiological problems for the indoor environment or they can be a part of the solution. Since fabrics destined for outdoor wear or sporting goods are subjected to moisture and dirt on a daily use basis, they are also destined for bacteria and fungal growth and the subsequent odors, staining, deterioration, and skin related problems. Many outdoor fabrics find themselves in these microbial-risk environments.

Microbiological problems have been minimized by recent technology of monomers, fibers, finishes, and finishing and coating materials. Construction, in some cases, has reduced microbiological problems by chemical and physical design. But, in most cases of microbial control, active intervention with an antimicrobial agent is needed and desired by customers. Antimicrobials are not all the same and each has positive and negative attributes depending on the end-use and processing needs. Maintaining customer focus while anticipating production and production technology needs are challenging yet attainable given the added value antimicrobial treatments offer. Adding to the complexity for the use of antimicrobials is the need for proper compliance with regulatory agencies in the countries of sale, use, and commerce.

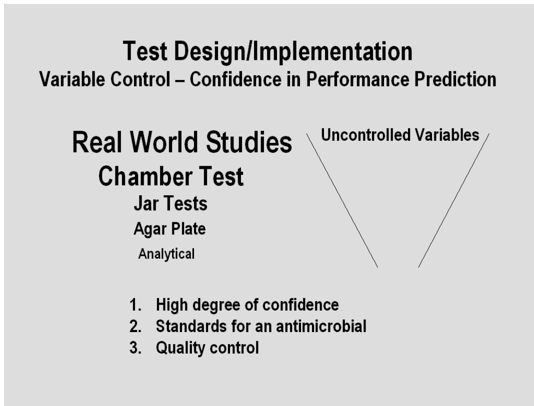

Fig.1. Test Design/Implementation

Although the development/ commercialization process seems complex, antimicrobial suppliers have positioned themselves to meet the harshest demands of product development specialists. The marketplace needs are diverse and the opportunities for extracting value from antimicrobial treatments are unending.

Value enhancing finish technologies can be developed around fads and fashion trends, but the most enduring finish technologies are designed to improve fabric performance and function. Antimicrobial treatment is rapidly becoming a standard finish in some textile categories and should be viewed as a finish with a future, because they enhance the treated product's performance while still meeting consumer-led feature needs and demands. Consumers expect greater sustainability by the control of algal and fungal contamination of outdoor performance fabrics.

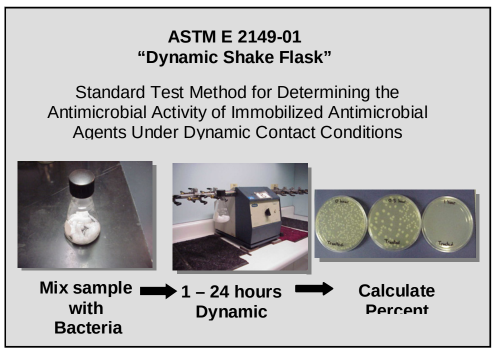

Fig. 2. Dynamic Shake Flask Test

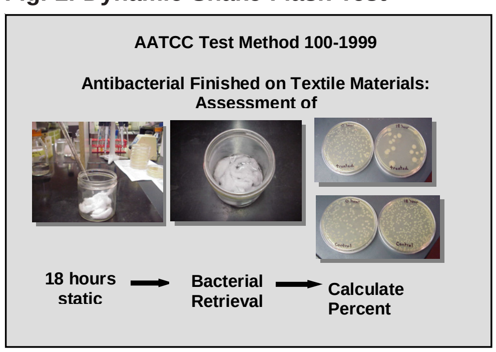

Fig. 3. AATCC Test Method 100-1999

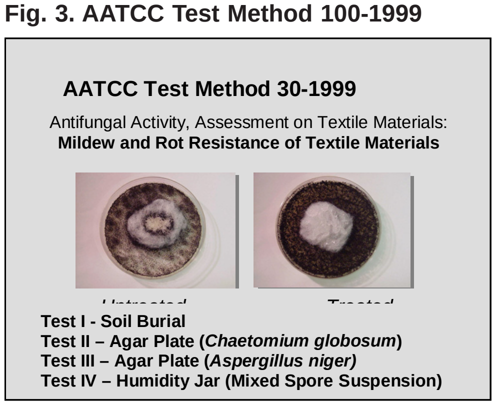

Fig. 4. AATCC Test Method 30-1999

TESTS

This practice of employing fast, reproducible laboratory tests to give an indication of real-life activity is now commonplace, but the absolute relationship between laboratory performance and real-life performance is not indicated solely with one test. The goal of every test method is to determine the effectiveness of any given chemical agent against a variety of microorganisms in the shortest amount of time. Such tests must also be able to simulate real-world stresses such as freeze/thaw conditions, UV light, rain, abrasion, or other environmental or wear conditions.

In studying test design and implementation there are many levels of controllable and uncontrollable variables. (Fig. 1) Real-life tests can include wear trials, odor panel studies, weathering, and other end-use stresses and simulations. To perform these types of tests on every antimicrobial treated product is impractical, expensive, and in some cases, impossible due to the number of samples needed to be statistically significant and still provide a product to the marketplace in a reasonable amount of time. Laboratory tests have been designed to give the highest degree of confidence to the end user that their treated article will perform as indicated on the products registrations and listings. These laboratory tests could include direct activity against microorganisms or simply indirect activity by virtue of the presence of the antimicrobial agent at specific levels. Whether the laboratory tests are indirect chemical assays or direct microbiological assays, the relationship towards real-life activity is still required. Once a link between laboratory data and real-life activity has been established, quick and reliable testing on newly produced material can be easily obtained.

The uncontrollable variables found in real world studies are enormous. The variables with laboratory tests can include the type of organism used and concentration (dose), temperature, time, and eventually the test operator. As we develop test methods directly demonstrating real-life activity or laboratory activity we must focus on reducing the uncontrollable variables.

Most antimicrobial laboratory tests methods cannot, by themselves, give a prediction of real life activity. However, if a direct correlation between real life activity and laboratory activity can be established, routine laboratory tests can efficiently predict real-life activity. For example, the durable organofunctional silane technology provided by ÆGIS Environments has been proven to be effective in many real-life situations. These tests include odor panels, retrieval studies, wear studies, and *In Vitro* and *In Vivo* biomedical implantation studies. In direct relation, these real-life samples have been tested in the laboratory using the ASTM E2149-01 and AATCC100 antibacterial tests (Figures 2 and 3), AATCC30-III, and ASTM G21 antifungal tests (Figure 4), the ASTM D 3273 chamber test (Fig. 5) and all of these tests with samples stressed in a weatherometer (Fig. 6). Actual field exposures have also been used to pre-stress samples for the lab tests for actual field results (Fig. 7). As this link has been established for real-life activity and application concentration, the confidence that laboratory test results are an accurate indication of real-life activity increases. With the reduction of uncontrolled variables in laboratory test methods, confidence and significance in test results increases.

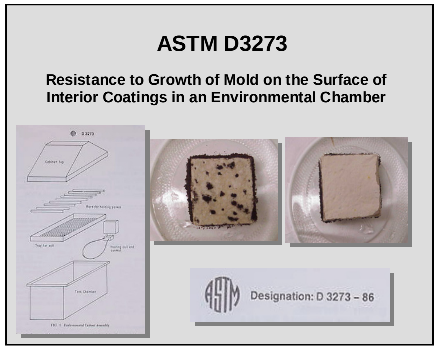

Fig. 5. ASTM Test Method D3273

Fig. 6. Weatherometer

Fig. 7. Natural Weathering Station, Miami, FL

CHOICES OF ANTIMICROBIALS

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, yeast, and algae. This control reduces or eliminates the problems of deterioration, staining, odors, and health concerns that such organisms cause.

In the broad array of microorganisms, there are both good and bad types. Antimicrobial strategies for destructive organisms must include ensuring that non-target organisms are not affected or that adaptation of microorganisms is not encouraged.

LEACHING ACTION

Antimicrobials do not all work the same. The vast majority of antimicrobials work by migrating 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 the challenges of providing durability for the useful life of products, leaching technologies have the potential to cause a variety of other problems when used in fabrics. These leaching properties can allow 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

PHYSICAL VS. CHEMICAL ACTION

An antimicrobial with a completely different mode of action than the leaching technologies is a molecularly-bonded unconventional technology. The unique bound 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. Dr. M. Bourgeois and researchers at the “Institute Textile de France” in Lyon have also 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 with broad-spectrum antimicrobial activity have been demonstrated.

Antimicrobial technologies are quite varied and the demands for application are equally varied. Depending on the technology, the intended end-uses, and the mode of antimicrobial activity, one or another application point and procedure are favored. Adding to the fiber polymer melt, to the fiber during processing, to a fabric coating or film, or to the fabric or finished goods, are all available alternatives.

Addition to the polymer melt or surface film coating is fraught with problems that must be evaluated if this application point is being considered. The performance challenge presented by creating a toxicant reservoir inside of a fiber or film when the contact with the microbe will be on the surface is dependent on the solubility constant of the antimicrobial, the way that it is embedded into the polymer matrix, the chemicals ability to move in the polymer matrix, and the nature of the environment around the fiber or film during use. Other challenges revolve around the need for uniform mixing and subsequent dose release of the antimicrobial, changes in fiber properties, negative effects on color or reflectance, blocking of process filters, build-up on process equipment, odor, fuming, efflorescence or surface salting problems, or chemical conversion problems considering probable process temperatures of 230°C for 2-3 minutes. Also of concern are the health and environmental issues for personnel, users, and the environment. Cost of such a strategy must be considered because of the need to use levels of chemical in the reservoir suitable for providing a useful and effective dose during the life of the end-use product. Even with these challenges, a variety of chemistries have been reported in the literature and are commercially available. These include some bis-chlorinated phenol products and silver based technologies.

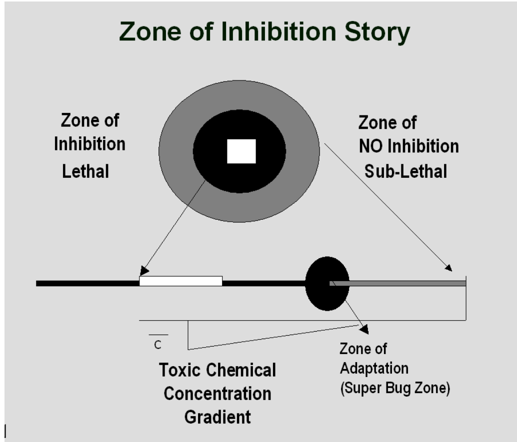

Fig. 8. Zone of Inhibition Story

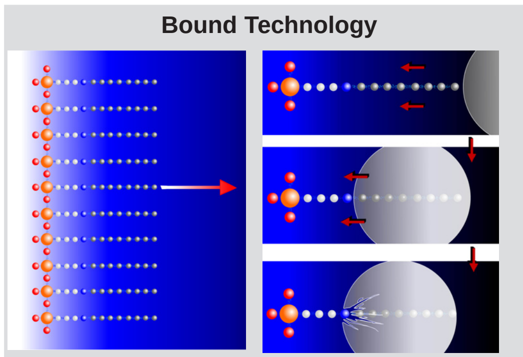

Fig. 9. Bound Technology

After a polymer is extruded into the fiber form, antimicrobials can be added with the drawing oils or spin finishes. This method has many merits if the issues of compatibility and uniformity can be solved and that properties of the spin finish are maintained. The fiber treatment must also be able to survive all of the downstream processing without interfering with the fiber processing or present any hazards to the workers, process equipment, or the environment.

In a similar fashion and with all of the same cautions, the antimicrobial treatment may be able to be added in one of the post drawing processing points. Adding at the crimper with or without the crimper oil can take advantage of the heat setting process to assure curing and durability of the antimicrobial binder or, in the case of the silanequat antimicrobial, enhance the bonding reactions needed to maximize durability.

Some antimicrobials, as reactive treatments or ones that are in binders, can be added to a spun bonded product, to the fiber batt, or to fibers or fabrics by spraying or pad bath. This can be done at the fiber processing plant or as a pre-step at the converters. This method allows for the treatment to be on the surface of the fiber yet still provides all of the needed compatibility and safety properties consistent with the process and the end-use. Simple deposition of the antimicrobial, although still practiced by some, is not a good alternative considering increased environmental and human sensitivities as well as concerns over sublethal antimicrobial doses allowing for microbial adaptation.

Another alternative is adding the antimicrobial on the final textile substrate. This can be done with spraying technology, exhaustion batch treatment processes, or with a pad bath. Foam applications have also been used effectively with the silanequat antimicrobial onto nonwoven batts or woven textile flat goods. Again, all of the needed compatibility and safety properties consistent with the process and the end-use must be assured.

For outdoor fabrics it is common to add the desired antimicrobial to the protective finish used the final “fabric.” This coatings delivery offers a reservoir for leaching technologies or a binding site for reactive antimicrobials. This delivery point requires UV stabilities, no color formation, compatibility with the coating chemistry, and the chemical and physical ability to survive and perform in the end-use environment.

SUMMARY

The outdoor performance materials industry has customer driven opportunities to capitalize on the use of antimicrobial treatments. Microbes cause staining and deterioration problems that affect the durability and quality of outdoor performance materials. Materials of construction and construction techniques have been used to minimize microbial problems but the need for active antimicrobials exist in almost all products and end-use environments. Chemistries available as antimicrobials are quite diverse and proper selection needs to address durability to end-use conditions, broad spectrum effectiveness, environmental and human safety, compatibility with substrates, regulatory status, as well as costs.

Test techniques are available to screen, qualify, and quality control check antimicrobial treatments for the full variety of end uses.

Armed with this information, designers of outdoor performance materials can work with the antimicrobial industry to meet their needs and the needs of their customers for protecting their products against the negative effects of microorganism.

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