Microbiological Problems Associated With Carpeting

Presented at the Unitex First World Congress – Carpets, May 2002 in Belgium

By W. Curtis White, ÆGIS Environments, Midland, MI
Robert Monticello, PhD., ÆGIS Environments, Midland, MI
Hugo Soens, Devan, Ronse-Renaix, Belgium

Abstract
Carpeting, as rugs, wall to wall, or carpet squares, must serve multiple purposes in our commercial buildings, residences, and a wide variety of vehicles such as cars, boats, and airplanes.

The technical requirements for carpets are as diverse as the end uses and must account for the use, abuse, and ultimate disposal.

The technical limits of carpet are more stretched then when challenged by microbiological problems. Microorganisms are part of our everyday lives and environments. When in balance they are positive, but when out of balance they cause untold damage in terms of odors, staining, deterioration, and human health.

Control of microorganisms can be accomplished by prudent choices of materials of construction, chemical treatments of fibers or constructed carpets, or by chemical additions to already installed carpeting.

This paper will cover the problems caused by microorganisms in carpeting and the chemical strategies employed in their control.

Introduction

Consumers frequently demand the right to control and select their environment with respect to colors, texture, temperature, humidity, odors, light, and sound. Carpeting constitutes a major environmental surface for both residential and commercial establishments. Consequently, the dyeing and finishing industries are constantly challenged to produce carpeting with desired and needed functional and aesthetic features.

A desirable feature, as shown in market studies, concerns freedom from foul odors. Carpeting by its construction and use provides a habitat for a large variety of microorganisms, some of which not only produce putrid and mildew odors, but also contribute to unsightly defacement and deterioration of carpet components. These microbes may also produce infectious and/or allergenic conditions in humans.[1-5]

The Need for Antimicrobial Treatment

The increased use of carpets in hospitals, schools, and other institutions demonstrates the need for an additional property in carpeting: the prevention of bacterial and fungal growth. The need is obvious in hospitals, where the greatest concern about carpeting is the possibility of infectious hazards.[2,4,5,10,11] However, the need for a safe antimicrobial treatment is not limited to hospitals. Inhibiting bacteria and fungi is equally important in carpeted areas of playrooms, convalescent bedrooms, sanitariums, and hotel/motel rooms. All of these areas may serve as a reservoir for potentially harmful bacteria and fungi. In addition, there is the problem of odor and deterioration

caused by the presence of microorganisms and their breakdown products. Extension of this need to the home is obvious as we consider the use of carpeting in bathrooms, kitchens, below-grade areas, recreation and family rooms, as well as other areas where pets and babies roam. The need for hygienic freshness is a reality in the consumer's mind.

Microbes

Microorganisms are a part of our everyday lives and include many diverse organisms. They include bacteria, fungi, yeasts, and algae that are found wherever moisture, temperature, food sources, and receptive substrates allow. They include thousands of different species, and are found everywhere in the environment as well as on our bodies. Some of these organisms are beneficial and a natural part of the environment. Others can and do cause serious problems including deterioration, defacement, rotting, surface degradation, staining of useful goods/substrates, and health problems ranging from simple discomfort to physical irritation, allergic sensitization, toxic responses, and infection.

Consumer and commercial operators are challenged by the presence of these microorganisms and the negative effects they cause. Antimicrobial treatments for bacterial, fungal, and mite control, are proving to be popular among consumers, manufacturers, and building operators. These treatments not only provide protection from microorganisms they also add aesthetic and emotive values to a full range of products. Deterioration, defacement, odors, and “harboring” medically significant microorganisms, are all dramatic effects we see in buildings and products where microbial contamination is present. The ability to make surfaces and carpeting resistant to microbial contamination has advantages and values in many applications and market segments served by the carpet industry.

Additionally, carpets require the need to control microscopic arthropods such as mites. Mites are associated with dirt and dust and their presence in bedding and other home furnishing products has been linked to allergenic responses in humans. Control strategies for these organisms are complex, taking into consideration the life habits of these organisms as well as their metabolic and reproductive habits.

The Impact of Microorganisms on Substrates

Microorganisms have an unending ability to adjust to their environments. Microbiological contamination of textiles (wovens and nonwovens), foams, other finished substrates such as carpet, raw materials, wet processes in the mills, roll or bulk goods in storage, and finished goods in storage or transport, can result in dire economical consequences. In addition this can be an annoyance and aesthetic problem to an athlete or consumer. These critical consequences can range from a product recall costing millions of dollars to product spoilage that requires untold resources. This can also cause the shut down of production facilities to redesign processes and products. If human health problems are incurred, the human toll in sick days, illness, and death, can be even more devastating, and the legal consequences can be staggering.

For years, the military has fought the problems associated with microbiologically contaminated material and equipment, especially in the field where exposure to continual moisture and use accelerates the formation of odors, staining, and degradation of military gear and equipment. In addition, the substrates themselves can harbor medically significant (pathogenic) microorganisms, thereby posing additional problems for the personnel, especially under crowded conditions.

The medical and research communities require antimicrobial protection for textiles, foams, and other substrates used in medical and research facilities, nursing facilities, veterinary clinics and hospitals, as well as the fabrics used for personnel attire and housekeeping supplies. This protection reduces odors due to microbial decomposition and the risk of infection resulting from

substrates that are contaminated with pathogenic organisms. It is especially predominate in hospitals and other institutions where crowded conditions prevail and there may not be an opportunity for frequent cleaning. In the 1950's, Stuart (1957) reported that surgical drapes treated with a residual bacteriostat prior to heat sterilization kept down the bacterial count during long operations, and that treatment of diapers and bed pads assisted in preventing the formation of ammonia from urea by bacteria in the urine of infants and incontinent patients. Hurst, et al. (1958) demonstrated that the air in hospital laundry chutes contained pathogenic bacteria, presumably from contaminated laundry. An extensive research study in 1982 (White and Olderman) on a nonwoven surgical drape treated with a silanequat antimicrobial (AEM 5700 Antimicrobial) indicated that this antimicrobial could reduce the levels of bacterial contamination on the drape itself, control and/or kill the bacteria commonly associated with surgical wound infections, take an active role in maintaining an aseptic field at the wound site, and allow the drape fabric to retain all the positive handling and appearance characteristics desired by the operating room (OR) and surgical staff. In 1979, this antimicrobial was listed by the FDA under the 510 (k) provisions of the Medical Devises Act for use on surgical drapes. It is registered with the Environmental Protection Agency (EPA) for use in other textiles.

Consumers are keenly aware of the problems caused by microorganisms and their awareness is reinforced daily by "press events" highlighting the risks associated with such contamination. They are concerned over the problem of odor, staining, deterioration, and human health conditions such as allergies, infectious diseases, and "sick building syndrome (SBS)." These concerns have led to their demand for goods and products for home, sports, and personal use, to be protected from the effects of microbial contamination.

According to some manufacturers, concern about microorganisms in the environment is another recent trend affecting a number of market opportunities, especially in the industrial wipes and garments industry. Medical clean-rooms, pharmaceuticals, and food industries, have been forced to recognize that inanimate surfaces (garments, other finished goods, building materials, and furnishings) can and do harbor microorganisms that affect the quality of the goods being produced and/or the health, welfare, and comfort to the occupants. Carpeting, soft goods, and furnishings have hit the top of the list regarding concerns for microbial contamination and amplification.

Control strategies for the contaminants, (i.e., the target microorganisms that have a negative impact on substrates) must include careful consideration for destroying them without affecting the non-target organisms and without allowing or encouraging the target organisms to adapt to the control chemical.

What Causes Microbial Growth?

The microorganisms represented in an environment are complex. Every element of this indoor environment, from its carpeting, furnishings, and occupants, offers a home for microorganisms. Microorganisms need moisture and nutrients, and more than 95% of them need to be associated with a surface.

Moisture results from catastrophic as well as normal events - a leaking roof, a sweating pipe, a leaking radiator, condensation on windows, condensation on more subtle surfaces where dew points are reached, humidified air from the HVAC system, or from hundreds of other sources. A hotel or resort facility compounds the problem with the moisture from pools, spas, individual air conditioners, and literally hundreds of bathrooms. This, along with wall-to-wall carpeting, draperies, wall coverings, furniture, bedding, and ceiling tiles, creates 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 skin, are shed continuously. Given acceptable growth conditions, some types can multiply from one organism to more than one billion in just 18 hours.

A building may be infested during construction and catastrophic events (particularly with fungi), but more commonly its occupants or air infiltration routes bring the organisms into the building. Fungi (typically outdoor organisms known as mold, mildew, yeast and dust mites) enter the building on clothing, are wafted in through open doors, or are pulled in as "make up" air by the HVAC system. Bacteria follow these same routes but are primarily associated with human carriers and very wet areas such a drain pans and places with constant or standing water.

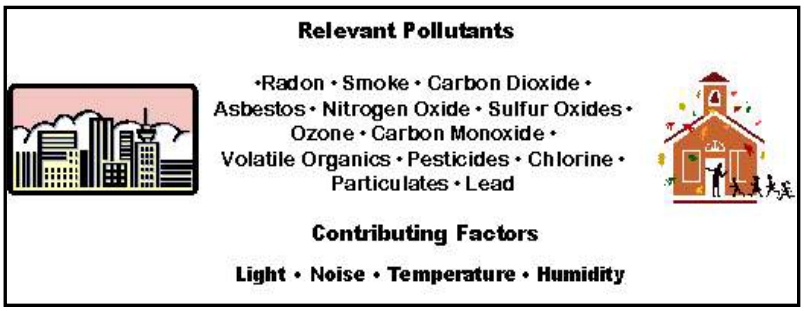


Fig. 1. Relevant pollutants

Airborne Pollution

Although most organisms grow on receptive building surfaces, they and their spores become airborne through normal occupant traffic and activities such as vacuuming. Once airborne, the HVAC systems, chases, and elevator shafts efficiently transport the microorganisms throughout the building. They settle on other receptive surfaces and quickly begin to reproduce. One good growth source for a particular organism can quickly result in outbreaks throughout the building.

Additionally, with the universal use of air conditioning, recycling air to improve energy efficiencies takes place. But that recycling tends to concentrate indoor air pollutants – including microorganisms and their annoying, irritating, sensitizing, and toxic by-products.

Control

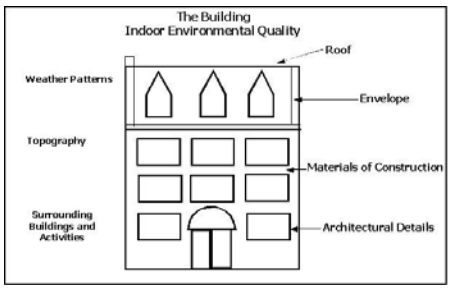


Fig. 2 The building indoor environmental quality.

If we look at microbes as a model, we can understand a great deal about the general sources of most indoor pollutants. Figure 1 shows some of these sources. Most or many of these can be habitats for microorganisms – food, water, receptive surfaces, and temperature are ideal. Carpeting becomes an ideal habitat for a wide variety of microorganisms.

With this short preface on the impact of IEQ issues, the nature of IEQ problems, and the range of causative agents, we now can introduce some concepts that are useful in identifying, solving, and preventing problems.

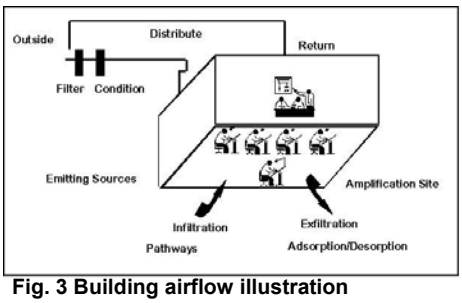


Fig. 3 Building airflow illustration

No effective testing, mitigation, or protection strategy can be created and implemented without a thorough evaluation of the building. The materials of construction, the operating systems, the furnishings, and the habits and practices of the occupants are critical components. Figures 2 and 3 illustrate this holistic view of a building's system. Auditing and understanding these critical pollutant generating and transmitting sources are vital to

environmental control.

To be appropriate and effective, strategies must incorporate a variety of control methods – source removal, dilution, filtration, and source control. In plain English, this means eliminating materials that exude excessive amounts of known pollutants, pumping massive amounts of fresh air into a building to dilute existing pollutants, preventing greater concentration, using improved filtration methods to remove airborne contaminants, and directly attacking pollutant sources to prevent creation of new contaminants. All are valuable tactics, yet they are limited and bear an associated price. Only effective source control delivers long-term benefits.

The cost/benefit ratio of many practices is questionable, and may only deal with short-term reduction of human symptoms rather than elimination of the basic problem. Like taking aspirin for arthritis pain, fever or headache, only the symptoms are addressed. In areas such as control of bacteria and fungi, there are highly effective services that provide long-term source control. By actively modifying the environmental surfaces in a building, the sources of microbial growth can be greatly reduced.

This approach can be used to remove existing microbial infestations, prevent microbial colonization, and reduce transient microbial levels. For optimal safety and technical performance, this line of attack requires use of a technology that is non-volatilizing, non-migrating (chemically durable), non-toxic to higher life forms, and has a proven record of real-world problem solving. The essence of this systems approach is expressed in Figure 4.

Fig. 4 Pollutants in a building environment.

Antimicrobials

In institutions, all flooring coverings, textile as well as hard surfaces, need to undergo periodic housekeeping to maintain hygiene and aesthetics.

This is particularly true of carpeted patient-care areas and buildings with high traffic or high humidity. For this reason, hospitals regularly use antimicrobial additives as part of their cleaning procedures. These additives are based on halogenated phenol derivatives, halogenated salicylic acid anilides, organotin compounds, quanternary ammonium compounds, and quaternary ammonium sulfonamide derivatives.

All of these compounds base their activity on leaching or diffusion into their surroundings. Such compounds must be reapplied often because they lack durability against washing, cleaning, and shampooing. Many also have limited effectiveness against specific pest microorganisms and thus have to be applied with other compounds to increase their spectrum of activity.

The term antimicrobial refers to a broad range of technologies that can 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 carpeting 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 carpeting 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 or consumers. The economic impact of microbial contamination is significant and the consumer interests and demands for protection is at an all time high.

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 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 nonwovens. These leaching properties can contact 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 more serious problem with leaching technologies is that they allow 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. 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 Function and 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 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 are often effective, but are used up in the process of working, wasted in random misses, or complexed by other chemicals in the environments of use and abuse. Some companies incorporate leaching technologies into fibers and slow the release rate to extend the useful life of the antimicrobial, even adding to them chemical binders and claiming 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 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 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 of inhibition test are run. These tests are used to measure the zone of inhibition created by a leaching antimicrobial and clearly define the area where the antimicrobial had come off the substrate and killed the microorganisms in the agar. Such a phenomenon can be explained in Fig. 5a and 5b. Figure 5a presents graphically a typical zone of inhibition test method. The blue area represents a textile material treated with a leaching antimicrobial. The clear zone surrounding the substrate represents the zone of inhibition and the sublethal zone is shown in gray. The area at which the zones merge is presented as the zone of adaptation. Fig. 5b shows actual results on the difference between the leaching and the non-leaching antimicrobial treatments on textiles both as first treated and then after five household launderings.

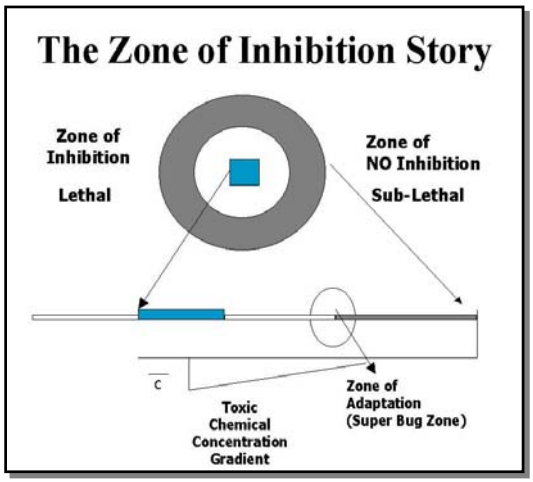


Fig.5a. Zone Of Inhibition Story

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 carpet industry as it chooses the antimicrobials to which it will be exposing the public and their workers.

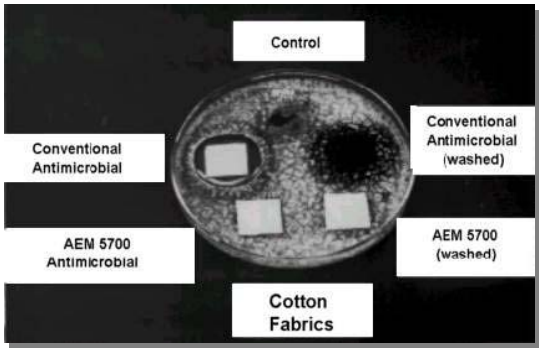
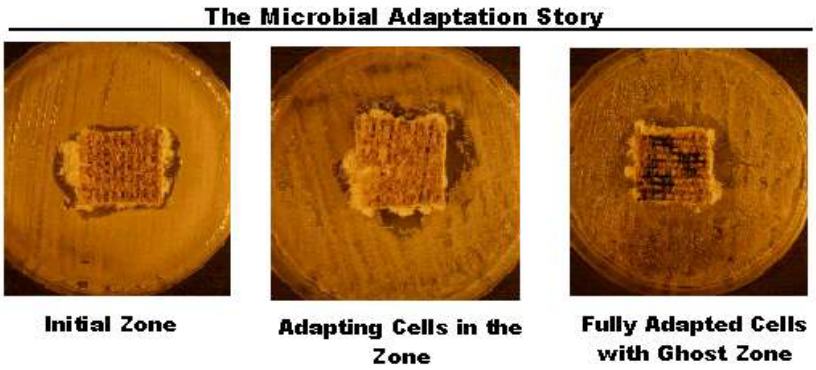


Fig. 5b. Washed durability

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 known as the zone of adaptation (Fig. 5a). 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 the following images 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 (Fig. 6a) and used to inoculate a new test plate. This second test plate (Fig. 6b) 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 (Fig. 6c). 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.



Figs. 6a,b, c. The microbial adaptation story – leaching antimicrobial treated carpet fiber

A significantly different and much more unique antimicrobial technology used in the nonwovens industry does not leach but instead 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. 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 quaternaryammonium 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 (Fig. 7). (2)

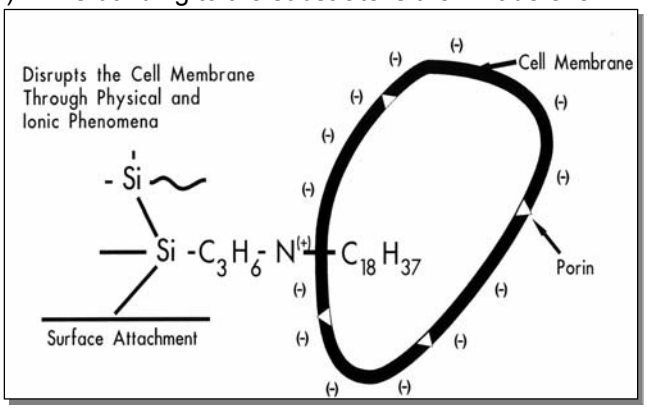


Fig. 7. Bonded chemical

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 causes 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 sword-like action and then electrocuted by a positively charged nitrogen molecule (Fig. 8). 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 inside manufacturing facilities or in actual end use situations.

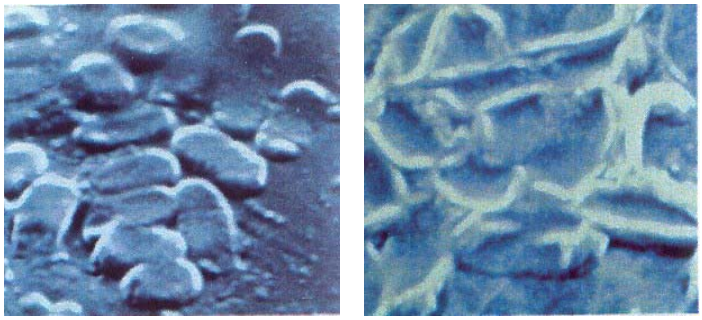


Fig. 8. Untreated Nonwoven **Treated Nonwoven-AEM 5700/5772**
Escherichia coli

Carpet Applications

In September 1981, the EPA granted Dow Corning an amendment for the use of Dow Corning® 5700 antimicrobial agent (now ÆGIS AEM 5700 Antimicrobial) on carpeting, giving rise to a new generation of carpet and carpet fiber features. The market for controlling mildew and putrefaction odors on carpet has been filled with powders, liquids, and aerosols designed to mask, modify, or absorb microbial-generated odors.

Today, the approach to serving this market segment is to prevent these odors by dealing with the cause via the ÆGIS antimicrobial treatment, rather than periodically attempting to deal with the symptoms. Of course, cooking, smoking, and other nonmicrobial-generated odors must still be dealt with by appropriate ventilation and housekeeping techniques.

ÆGIS Treatment

The active ingredient (3-trimethoxysilyl-propyldimethyloctadecyl ammonium chloride) of the ÆGIS antimicrobial treatment offers safety and efficacy advantages not found with other hygienic finishes. This compound combines two technologies: the binding mechanisms of alkoxysilanes, with the microorganism-killing ability of conventional quaternary ammonium antimicrobials. This results in a carpet with these benefits:

1. The treatment is durable and resistant to repeated washing, cleaning, and shampooing of the carpet. (Addendum, Tables I and II).

2. It has a broad spectrum of biological activity, i.e. bacteria, fungi, and yeasts are killed or suppressed from their development and rendered incapable of increasing in numbers when they contact the treated surface. (Addendum, Tables III and IV)

3. The ÆGIS antimicrobial treatment is compatible with other finishes and is generally applicable

using the usual finishing methods of the carpet manufacturer. (Addendum, Table V)

4. When used as directed, it is safe to man and the environment. Over 30 intensive toxicological and environmental tests have been performed and reviewed by the EPA for the active ingredient of the ÆGIS treatment.

5. Clinical evaluations demonstrate that textiles with the ÆGIS antimicrobial treatment effectively reduce and inhibit the growth of odor-causing bacteria.[8]

6. Lack of adaptation of bacteria to the presence of the ÆGIS antimicrobial treatment on untreated surfaces has been demonstrated using traditional techniques (Addendum, Table VI)

7. Extension of this finishing technology has also been demonstrated for nylon carpet fibers. (Addendum, Table VII)

8. Bacterial reduction of greater than 99% demonstrated in a German Research Center Study. (Table VIII)

Anti-Mite Treatments

In order to limit the increase of mite populations and the exposure risks associated with the presence of mites and their allergenic elements, treatments must be able to interrupt the life processes of the mites or alter their environment in ways that discourage their presence and reproduction. This is essential for nonwovens in pillows, bedding products, household products, flooring materials, stuffed toys, and other nonwoven products used in the indoor environment.

Millions of people suffer from allergies, skin irritations, asthma, or other respiratory diseases. The three major sources of indoor allergens associated with sensitization and subsequent allergic disease are dust mites, pets, and molds. Studies in different populations have shown that up to 85% of people have allergic asthma, but only 5-30% of the non-asthmatic population are allergy prick test positive to mites.

Mites belong to the Class Arachnida, as do spiders. Mites are small (300-400 μm) and are often found living in mattresses, sofas, carpets, and many other synthetic and natural fibers. 100,000 mites may live in one square meter carpet. Each dust mite will produce about 20 fecal pellets (10-40μm) per day, which is the known real allergenic trigger.

Mites feed on desquamated human skin. These skin cells are too dry for the dust mites to digest so they need to be broken down into a digestible food, which is facilitated by the fungus *Aspergillus repens*. By eliminating the *Aspergillus repens*, and therefore, the substance that dust mites feed on, the ÆGIS antimicrobial is controlling the increase of dust mite population.

To illustrate, ÆGIS AEM 5700/5772-treated mattress ticking was evaluated for dust mites by an independent laboratory (P.C.C.-Belgium) for 6 weeks in a semi-natural environment. A population reduction of 98% was observed compared to the population of an untreated mattress ticking (Table 1).

A similar test has been run by T.E.C. – France using the NF G-39011 French standard on acrylic fiber and polyester fiber. The ÆGIS treated fiber revealed a population reduction above 90% in both compared to an untreated sample.

For many years companies sought to control the common dust mite in bedding materials by using organotin chemistries provided by a number of suppliers. These leaching chemistries provided for actual killing of the mites when the difficulties of dose delivery could be controlled. These suppliers have only recently acknowledged long held concerns about the negative impact of these chemicals on the environment. This useful but limited mite control tool is not in use today by stewardship conscious companies.

Installed Carpeting Treatment Success

New carpeting can benefit from antimicrobial treatments, but it is also very beneficial to have antimicrobial technology safe enough, effective enough, and easy enough to use in a post installation setting.

Case Study

The Arthur G. James Cancer Center Hospital and Research Institute

The study building is a 12-story comprehensive cancer center and research institute located in Columbus, Ohio. Just prior to its opening in January, 1990, a ruptured water pipe on the 12th floor flooded the building with an estimated 500,000 gallons of water. Ceilings, walls, carpeted floors and upholstered furnishings were either wet or exposed to high humidity.

After assuring that the building's structural integrity had not been compromised, attention focused on restoring the microbiological quality of the building to levels consistent with its intended use, particularly in Bone Marrow Transplant and other areas where immunosuppressed patients would be housed.

Despite high efficiency air filtration, and widespread use of a chlorine-based disinfectant fog throughout the building and its ventilation system, large numbers of fungi and bacteria were retrieved from the air in all areas of the hospital. Large numbers of water-associated bacteria, such as *Acinetobacter sp*., as well as fungi were retrieved from carpeting.

Prior to the flood, hospital and university researchers had designed a study protocol to investigate the effect of surface modification with silane antimicrobials on infection rates within Bone Marrow Transplant, Hematology and Oncology areas in the hospital. The flood and subsequent microbial contamination preempted the study. But, investigation of various antimicrobial systems to achieve sustained microbial control during the study provided an important tool for use in remediation, and beyond.

All accessible interior surfaces (including carpeting, ceilings, walls, above ceiling space, furnishings, elevator shafts, mechanical and electrical chases) were treated with the organosilicon antimicrobial 3-trimethoxysilylpropyldimethyloctadecyl ammonium chloride (ÆGIS™ Antimicrobial) (6) in water in accordance with the manufacturer's application specifications. The applications were randomly tested for uniformity and penetration throughout the treatment process.

Results

- Pre-treatment retrievals were in a range of 721 – 2,800 CFU's/m^3. Of the 209 sample sites, 122 (58%) sites produced 2,800 CFU's/m^3, the upper detection limit of the sampler.

- Post-treatment sampling during the seven months following restoration of the building produced an average of 4.1 CFU's/m^3 at 643 sites. Retrievals were in a range of 0-25 CFU's/m^3. Of the sample sites, 289 sites (45%) produced 0 CFU's/m^3; an additional 231 sites (36%) produced retrievals in a range of 1-5 CFU's/m^3.

- The second post-treatment samplings were performed in 1991 at 82 sites randomly selected by floor. The samplings produced retrievals in a range of 0-9 CFU's/m3, with an average retrieval of 0.8 CFU's/m3. 40 sites (48%) produced 0 CFU's.

- The final post-treatment samplings were performed in 1992 at 86 sites randomly selected by floor. The samplings produced retrievals in a range of 0-4.7 CFU's/m^3, with an average retrieval of 0.4 CFU's/m^3. 56 sites (65%) produced 0 CFU's.

- Each of the 24 Bone Marrow Transplant patient rooms was negative for microorganisms during all of the post-treatment samplings.

The facility is presently free of odor and has a new appearance unaffected by the extensive application of a surface antimicrobial. No fungal nosocomial infections were recorded in this facility during the 30-month study and a post study check after five years. All renovations or reconstruction in the facility were strictly controlled and all newly added or modified surfaces were treated with ÆGIS antimicrobial for five years after the initial treatment.

Summary

Armed with knowledge of the strengths and weaknesses of antimicrobial treatments every marketer of carpet can assess their customers' needs and the values that such treatments can bring to the marketing of their products.

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 germs, bacteria, mold, mildew, yeast, and mites, on all kinds of nonwovens for the useful life of the products.

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. 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 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 demand for antimicrobial/antibacterial products as well as the antimicrobial/antibacterial performance needs of the textile 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:

1) 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 all to have function, it leaches or moves and has the potential to cause problems to people and the environment.

2) 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.

3) Adopting a non-leaching antimicrobial that doesn't pose the risk of creating adaptative resistant microorganisms.

4) Adopting an antimicrobial technology that is registered with the EPA, the EU, and other regulatory agencies for the specific product it is applied to.

5) Adopting an antimicrobial technology that can be tested for proper application at the mill or at the retailers. A verifiable quality assurance program should be a key component of any application process.

6) 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) Snyder, J., *Canadian Hospital*, 13, 1966, P. 56.
(2) Walter, W.G., *Health Lab. Sci.*, 6, 1969, P. 140.
(3) Baker, P.G.H., *New Zealand Medical J.*, 1977, P. 88.
(4) Schaffer, J. G., *Health Lab. Sci.*, 3, 1965, P. 80.
(5) Lanese, R. R., *Amer. J. Pub. Health*, 63, 1978, P. 171.
(6) Plueddemann, E.P., *J. Adhesion*, 2, 1970, P. 184.
(7) Isquith, A. J., *Appl. Micro*., 24, 1972, P. 859.
(8) Gettings, R. L., *AATCC Book of Papers*, 1978, P. 259.
(9) Malek, J. R., *J. Coated Fabrics,* 12, 1982, P. 28.
(10) Walter, W. G., *J. Environ. Health*, 30, 1967, P. 293.
(11) Anderson, R. L., *S. Clinical Micro.*, 15, 1982, P. 408.

Submitted:

www.microbeshield.com

www.devan.net

Addendum

Table I

Antimicrobial Activity of Nylon Carpet with the ÆGIS Antimicrobial Treatment in a 36-Month Use Study at Duke Hospital

Sample: Nylon carpet	Percent Bacterial Insult[1] Reduction[2]			
	Before Installation	12 Months wear, 1.5 M traffics	22 Months wear, 3 M traffics	36Month wear, 4.5M traffics
Untreated control	0	0	2.3	3.8
ÆGIS Antimicrobial	85	91	78	87

1. Bacterial inoculum was *Klebsiella pneumoniae*.
2. Average of triplicate tests.

Table II

Antifungal Activity of Nylon Carpet with the ÆGIS Treatment

Twelve-Week Tropical Chamber Exposure

Sample	Percent covered by fungi No. of weeks exposure[1]		
	1 weeks	6 weeks	12 weeks
High Density Nylon Control			
Unwashed, no shampooing	100	100	100
7 shampoo cycles[2]	100	100	100
14 shampoo cycles	100	100	100
21 shampoo cycles	100	100	100
High Density Nylon with ÆGIS Treatment			
Unwashed, no shampooing	0	0	0
7 shampoo cycles	0	0	0
14 shampoo cycles	0	0	0
21 shampoo cycles	0	0	0

1. Samples were re-challenged with a spore suspension of *Aspergillus niger* and *Penicillium* variable at 3, 6, and 9 weeks of the study.
2. Cleaning agents used included Fiber Fresh®, Blue Luster®, HR3®, and Woolite®. Data are representative of all test conditions.

Addendum (cont'd)

Table III

Efficacy of ÆGIS 5700 Antimicrobial Agent Against Microorganisms of Medical and Economic Importance

(This table indicates the broad spectrum of activity exhibited by ÆGIS 5700 and represents only a small number of the total microorganisms which could be controlled. ÆGIS 5700 is the antimicrobial component of the ÆGIS antimicrobial treatment.)

Bacteria	Yeasts	Fungi
S. aureus	*S. cerevisae*	*A . niger*
S. faecalis	*C. albicans*	*A. flavus*
E. coli		*A. terreus*
S. typhosa		*C. globosum*
S. choleraesuis		*A. verrucaria*
P. aeruginosa		*P. funiculosum*
M. smegmatis		*T. interdigitale*
M. tuberculosis		*P. pullulans*
S. mutans		*T. maidson*
K. pneumoniae		*C. fragens*
E. agglomerans		
S. epidermidis		
A. calcoaceticus		

Table IV

Control of Bacterial Clinical Isolates on Rugs
with the ÆGIS Antimicrobial Treatment

Sample	Organism	% Reduction
Control		0
Treated	*Streptococcus fecalis* wound isolate	100
Inoculum		0
Control		0
Treated	*Staphylococcus aureus* wound isolate	100
Inoculum		0
Control		20
Treated	*Escherichia coli* urine isolate	99+
Inoculum		1
Control		47
Treated	*Klebsiella oxytoca* urine isolate	100
Inoculum		1

Addendum (cont'd)

Table V

The ÆGIS Antimicrobial Treatment Compatibility with Carpet Processing

Available Carpet Process	Potential Application Process	Anticipated Antimicrobial Activity Percent reduction[1]
Kuster	Pad/spray/foam	>99.9
Beck	Pad/exhaust/spray/foam	>99.9
Sock or Yard	Pad/exhaust/spray/foam	>99.9

1. Percent reduction - CTM-0923 test organism *K. pneumoniae* ATCC 4352

Table VI
Bacterial Adaptation Studies on Nylon Carpet Processed with ÆGIS Antimicrobial Treatment

	Percent Reduction[1]										
	Klebsiella pneumoniae					Staphylococcus aurus					
Exposure[2]	1	2	3	4	5	1	2	3	4	5	
Nylon Control	0	0	0	0	0	10	5	9	13	26	
Nylon with ÆGIS	99.8	99.6	98.8	97.5	99.9	98.6	97.5	96.3	99.4	98.8	Treatment

1. CTM 0923 shake flask test
2. Shake flask survivors were used for subsequent exposures.

Addendum (cont'd)

Table VII

The ÆGIS Antimicrobial Treatment
Compatibility with Carpet Fiber Processing

Nylon Carpet Fiber Stage	Percent Reduction[1]	
	Klebsiella pneumoniae	Staphylococcus aureus
Extrusion	Not tested	Not Tested
Finish application	99.99	100
Drawing approx. 3X	99.99	99.99
Texturing (steam jet)	99.99	99.99
Crimp set–continuous	99.99	99.99
Crimp set–autoclave	99.99	98.6
In carpet mill		
Carding (staple fiber)	Not tested	Not Tested
Spinning (staple fiber)	Not tested	Not Tested
Autoclave set	98.7	99.99
Superba set	97.6	98.4
Suessen set	99.99	99.99

1. CTM 0923 shake flask technique

Table VIII
Percent Bacterial Reduction

Bacteria	ATCC #	Untreated(%)	Treated	7[1]	14	21
Staphylococcus aureus	ATCC 6538	0	98.9	98.9	98.0	98.7
Streptococcus faecalis	ATCC 6057	0	>99.9	99.9	98.0	96
Escherichia coli	ATCC 11229	0	>99.9	>99.9	>99.9	>99.9
Pseudomonas aeruginosa	ATCC15442	0	>99.9	>99.9	>99.9	>99.9
Klebsiella pneumoniae	ATCC 4352	0	>99.9	>99.9	>99.9	>99.9
Streptococcus mutans	DSM 20381	0	>99.9	>99.9	>99.9	>99.9
Salmonella typhi	ATCC 11060	0	>99.9	>99.9	>99.9	>99.9
Yeast						
Candida albicans	ATCC 10231	0	>99.9	>99.9	>99.9	>99.9
Mold [2]						
Trichophyton mentagrophytes	ATCC 9533	100	0	0	0	0
Aspergillus niger	ATCC6275	100	0	0	0	0

1. Number of shampoos
2.Fungal rating scale: 100=complete growth, 0=no growth.

Table IX: EFFICACY ASSESSMENT OF ACARICIDAL TREATMENT APPLIED ON TICKING SAMPLES. POPULATION OF THE MITE *DERMATOPHAGOIDES PTERONYSSINUS* ON EACH UNIT AFTER SIX WEEKS OF INCUBATION AT 25°C AND 75% RELATIVE HUMIDITY.
(50 starting mites: 25 pairs of young adults)

	3 Replicates/Sample			Mean	S.D.	Reduction
ÆGIS Treated	20	37	13	23	12.34	98.7%
Untreated	1799	1902	1726	1809	88.43	

*Pest Control Consultants VZW-ASBL, Dorpsstraat 24, B-9320 EREMBODEGEM, Belgium. August 9, 2000. "Test on the limitation of house dust mite populations in textiles Mattress Ticking treated with ÆGIS Microbe Shield