Antimicrobial Treatment on Wallboard Paper
Where Economy Meets Functionality

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INTRODUCTION

Innovation in building materials is driven by a range of economic and regulatory factors:

- Better end-use performance
- Energy savings
- Supply chain challenges
- Regulatory and legal concerns
- Pricing
- Contaminant and pollutant control

Recent press events, court cases, legislative actions, and insurance industry practices in Texas, California, Florida, and other states have required builders and building materials supply companies to redefine their role in dealing with the issue of microbial contamination. Anthony J. Barron, of Thelen, Reid, and Priests, LLP states, "Virtually every participant in the building industry - owners, contractors, designers, and material suppliers – faces some potential exposure to mold claims."[1]

Here are some key facts:

- Based on 2004 insurance industry estimates, mold related damage accounted for $2.5B/year in insurance claims and there are over 10,000 mold-related lawsuits currently pending. [2]
- Contractors and Architects are also the targets of mold lawsuits in addition to suppliers of building materials.
- Reacting to growing publicity over mold, at least 19 states have introduced legislation dealing with mold assessment and remediation.[3]
- According to the EPA, potential health effects and symptoms associated with mold exposure include allergic reactions, asthma, and other respiratory complaints.[4] Microbial contamination (mold, mildew, bacteria, algae, etc.) is the leading cause of indoor environmental contamination and has generated serious concerns in the construction and building industries.

The industry is definitely responding. Today's building products marketplace has an ever increasing array of products in the market that offer some form of microbial control – anywhere from ceiling tiles and gypsum board to counter tops and flooring. This market niche has flourished in recent months, but left a void in an area where microbial control is paramount – commodity building materials. These materials make up the bulk of the structure of home or small commercial buildings where protection from the negative effects of microorganisms is needed most.

How big is this opportunity?

According to the National Association of Home Builders (NAHB), as of 2002, the housing industry accounts for 14% of the nation's Gross Domestic Product and construction of 2MM single and multi-family home starts each year, thus supporting 4.9MM jobs, $159,000MM in wages and >$85,000MM in federal, state and local revenues

Historically it was believed that commodity building products were devoid of the need for added features, after all, price points were paramount and added steps in manufacturing proved costly and time consuming.

In recent months we have seen a shift in that perception. Commodity manufacturers – wallboard paper manufacturers particularly - are realizing that antimicrobial protection doesn't have to be costly, leave unwanted chemical legacies, and most importantly, can be easily applied and verified while enhancing other product properties.

This offers an opportunity for the building materials industry to bring value and to expand its presence in their massive market. Through the proper education and choice of antimicrobial protection available today, specifiers, contractors, and building products manufacturers can protect themselves in this volatile and potentially expensive issue.

Impact of Microbial Growth on Construction Materials

Microbial contamination (mold, mildew, bacteria, fungus) is a leading cause of indoor environmental contamination and has generated serious concerns in the construction and building industries. Recent court cases in Texas and other states have required builders and OEM producers of construction materials to deal with the issue of microbial contamination during construction.

Construction materials, which are important components of the building envelope, are key factors to indoor environmental quality. Virtually any housewrap, insulation, sealant, and exterior or interior treatment, can create significant microbiological problems for the indoor environment.

Microbes are diverse, found everywhere, and highly adaptive. They cause short- and long-term problems within buildings through the staining and deterioration (corrosion, rotting, etc.) of the structure as well as the generation of foul odors in the living environment. They can also cause human problems such as Building Related Illnesses (BRI), Sick Building Syndrome (SBS), Hypersensitivity Pneumonitis, allergic disorders, and infectious disorders (including Legionnaire's Disease).

The microorganisms represented in a building are complex. Every element of a building, from its furnishings to 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 can result from catastrophic as well as "normal" events – i.e., a leaking roof, a sweating pipe, a leaking radiator, condensation on windows, condensation on drywall surfaces where dew points are reached, humidified air from the HVAC system, or from dozens of other sources. These problems are magnified in a hotel or resort facility by the moisture from pools, spas, individual air conditioners, and literally hundreds of bathrooms. These conditions, along with wall-to-wall carpeting, 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 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 can be infested during construction or as a result of catastrophic events (particularly with fungi). Fungi (typically outdoor organisms known as mold, mildew, and yeast) enter the building on worker's 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.

Strategies for Microbial Control

In the past, the "passive guidance" approach has been used to direct builders and manufacturers to control the moisture level in the environment as the strategy to address microbial problems. Oakland County, CA Public Works Agency, for example, in its "Strategy 4.3: Control Moisture to Prevent Microbial Contamination," directs as its primary strategy, "Minimize the accumulation of undesirable moisture on the site and/or outdoor spaces."[5] Although this is good guidance, it is not a comprehensive solution to the problem. Moisture management is only one aspect in microbial control and to ignore its complexity exposes builder and manufacturer legally and financially.

Another strategy was is to remove the source of "food" by replacing paper and wood with fiberglass and masonry. This can be cost prohibitive if implemented throughout new construction.

A new, active approach is gaining momentum as the industry searches for new, inexpensive ways to address the issues of microbial control, not only for legal purposes, but also for the protection of their products throughout the manufacturing and supply chain. Although deemed useful and most likely necessary, antimicrobials in the construction and building products industry have been least understood given the wide array of biocidal, fungicidal, disinfectants, and sanitizers on the market as well as the "legacy" of toxicity they leave behind.

Antimicrobials

The term antimicrobial refers to a broad range of technologies that provide varying degrees of protection for products and buildings against microorganisms. Antimicrobials, as a group of materials, 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 widely used on textiles to control bacteria, 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, the presence of certain types are beneficial while other types are not. Antimicrobial strategies for undesirable organisms must include ensuring that non-target organisms are not negatively affected or that adaptation of microorganisms is not encouraged.

Antimicrobial Treatments

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. These leaching antimicrobial technologies 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.

A significantly different and much more unique antimicrobial technology used in the building materials industry does not leach but instead remains permanently affixed to the surface on which it is applied. This bound antimicrobial technology, an organofunctional silane, has a mode of action that relies on the chemistry remaining affixed to the substrate - killing microorganisms as they contact the surface to which it is applied. The attachment of this technology to surfaces involves two processes. First and most important is a very rapid process, which coats the substrate (fabric, fiber, etc.) with the cationic species (physisorption). 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. Once polymerized, the treatment does not migrate or create a zone of inhibition, thus preventing conditions that allow for adapted organisms. After they have coated the surface in this manner, they become virtually non-removable, even on surfaces with which they cannot react covalently.[6] Unlike leaching technologies, it does not poison the microorganism. When a microbe contacts the organofunctional silane treated surface of the substrate, the cell is physically ruptured by a sword-like action and then electrocuted by a positively charged nitrogen molecule. Effective levels of this technology do not leach or diminish over time.

Because this technology is affixed and bonded to substrate, it does not cross the skin barrier, affect normal skin bacteria, nor cause rashes or skin irritations. This type of antimicrobial technology has been safely and effectively used for over three decades in textiles that are likely to have human contact or where durability is of value – i.e., medical and surgical textiles, diapers, intimate apparel, footwear, etc. A variety of wovens, nonwovens, building materials and interiors and surface, to virtually all types of fabrics have benefited by this durable treatment.

Safety Profile

It is critical to review all uses of chemicals used in the building materials industry in light of the intended use and the toxicological profile of the chemical. This is especially relevant as one remembers that antimicrobials, by definition and function, inhibit and/or kill living things. The mode of biological involvement needs to be fully understood so that a proper balance between risks and benefits can be made. For illustration, the following safety profile of the bonded antimicrobial technology can be considered a minimum profile of needed data for qualifying antimicrobial treatments on any surface.[7]

> The ability of the silanequat, when properly applied, to chemically bond to the textile substrate and still provide for the broad-spectrum control of microorganisms, makes it well suited to the safety challenges encountered in the full range of applications used in the medical industry.
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> The following studies have been conducted with the silanequat: (a) acute oral, (b) acute ocular, (c) acute and sub acute dermal, (d) acute vapor inhalation, (e) primary skin sensitization and irritation, (f) sub-acute vaginal irritation, (g) four-day static fish toxicity, (h) teratogenic evaluation, (i) sub-acute human wear test (socks), (j) human repeated insult patch test, (k) in-vitro Ames Microbial Assay with and without metabolic activation, (l) in-vitro mammalian cell transformation in the presence and absence of exogenous metabolic activation, (m) in-vitro Host-Mediated Assay and (n) a percutaneous absorption study. Although certain handling cautions are indicated by data from the above tests, no untoward effects are notable regarding treated substrates.
>
> Further to these studies, Olderman reported on studies done by American Hospital Supply (Baxter Health Care), for a surgical drape that had been treated with the AEM 5700/5772 treatment. These studies included the following pre-clinical biocompatibility tests that are considered appropriate for skin contact medical products: (a) Tissue culture (cytotoxicity), to determine if a tissue culture medium (with serum) eluate of the test material can induce a cytopathic effect on monolayers of human (WI-38) cell, (b) Acute systemic toxicity to evaluate the potential of a single injection of an extract of the test material to produce a systemic toxicity response, (c) Intracutaneous irritation to evaluate the potential of a single injection of the test material extract to induce tissue irritation, (d) Eye irritation to determine the response of the rabbit eye to the instillation of specific extracts of the test material, (e) Hemolysis to determine if a substance can be extracted from the material which is capable of inducing hemolysis of human red blood cells, (f) Human Repeated Patch Test to determine if the test material is capable of inducing skin irritation and sensitization under controlled patch test conditions and (g). Extensive leachability studies to evaluate the durability and non-leaching potential of the chemically modified fabric when exposed to copious amounts of physiological saline, water and simulated human sweat.

The final results of these biocompatibility studies from the Olderman report indicated that the AEM 5700/5772 Antimicrobial treated fabric is non-toxic, non-irritating and non-sensitizing to human skin, and has a permanent antimicrobial capacity that cannot be extracted in use. These pre-clinical studies provide sufficient information to allow us to predict the biocompatibility of the finished products and support their safe clinical use. As such, the treated fabric was considered safe for use in surgery. Years of clinical use with no untoward effects also support the suitability of the treated fabric for its intended use.[7]

Performance

Among the many challenges faced in choosing the right antimicrobial technology for the building materials and construction industries include:

- Durability: Construction materials need durable features. End-uses of materials engineered for use on construction sites must have antimicrobial treatments that can survive abrasion, wet/dry cycles, freeze/thaw cycles, and other physical and chemical stresses.

- Waste Control/Toxicity: Antimicrobials control a range of microbial pests but in their use must be chosen and engineered so that they do not affect good and helpful microbes as well as be safe for the environment and human skin contact.

- Spectrum of Activity: Many materials are antimicrobial at the right concentration but it is very important to have as broad of 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 (+) bacteria, Gram (-) bacteria, yeast, and mycelial fungi. Added spectra could include algae, virus, or other microbial pests. Ever more, specialized chemistries have activity against tuberculosis, other pathogenic organisms, or microbial spores.

- Adaptation: Any soluble agent that affects a microorganism's life has the potential to set up conditions where the microbial cells adapt or mutate into resistant types. Use of standard disinfectants or sanitizers call 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.

Engineering the right antimicrobial usage requires a thorough understanding of the end-use and subsequent use and abuse of the finished goods. In the construction industry, building materials have proven a potential utility 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 construction and building products.

- Construction Materials: Roofing, envelope, and inside finishing materials integrated with an antimicrobial can offer installation and performance properties that make them a preferred choice over any alternatives. Antimicrobial treatments enhance the value of these products.

Details associated with the preparation and treatment of handsheets

Initial work to determine the most appropriate method of application and the level of treatment was conducted by preparing and treating handsheets. This work was completed at Western Michigan University (WMU) in collaboration with Richard Reams, the Director of the Paper Pilot Plant.

The paper pulp furnish concentration was adjusted to 0.24% fiber concentration. Using 550 gms of diluted furnish resulted in 1.3 gms of fiber / handsheet (8in X 8 in). This basis weight is consistent with that used for the top ply on the kraft paper.

Initial zeta potential of the diluted furnish: -20 mv.

The zeta potential of the dilute furnish was adjusted to neutral using commercially available polydadmac prior to the formation of a handsheet. Once formed, each handsheet was spray treated with a dilute aqueous solution AEM 5772, which is commercially available from ÆGIS Environments. Typical solution concentration ranged from 1-4% of the active ingredient. After spray treatment, the handsheet was dried using a drum dryer. Figure 1 illustrates the apparatus used at WMU to prepare handsheets.

Fig. 1. Handsheet machine.

Test Methods

In this study on wallboard paper treated with the bonded antimicrobial technology, it was imperative to determine the treatment level needed to ensure proper microbial inhibition and the durability of the treatment to withstand real-life abuses such as exposure to the elements and potential "water events" that can occur during and after installation.

There are test methods available in the field as well as in the lab to give the manufacturer and specifier the needed assurance that the antimicrobial treatment is properly applied, effective, and durable. The following test methods were used to determine the reactivity, efficacy, and durability of the antimicrobial treated wallboard paper.

ASTM D3273 – Environmental Chamber Test – Fungal Testing

This test method involves the use of a small environmental chamber to evaluate reproducibly the relative resistance of the antimicrobial treated wallboard paper to surface mold and mildew growth in a severe interior environment.

The results (Figs 2 and 3) indicate that the treated handsheets responds well to the bonded antimicrobial.

Based on the results of the ASTM D3273 testing, the handsheets treated with the bonded antimicrobial provided protection against microbial attachment, compared to untreated controls. The results are illustrated in Figure 2.

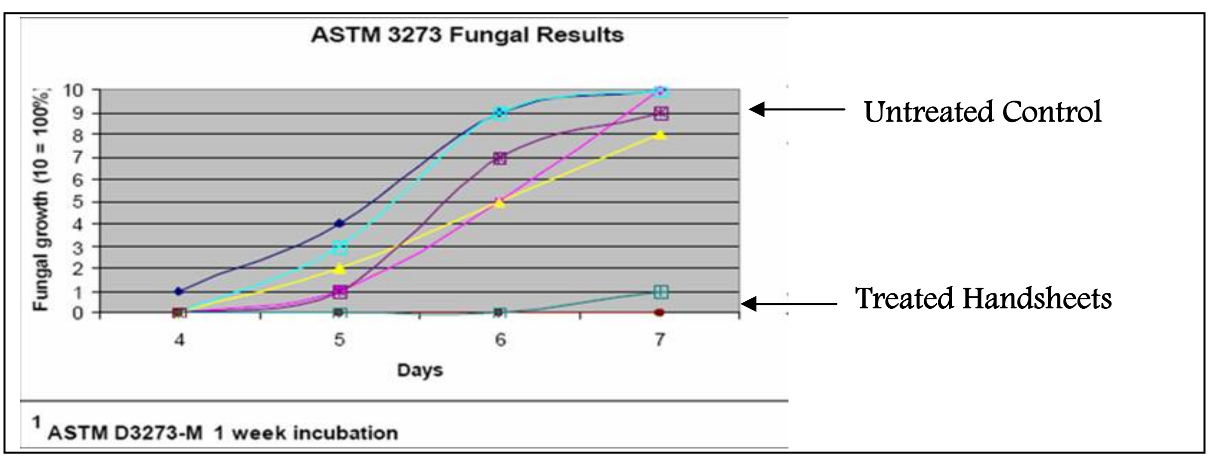

Fig 2. Percentage reading of fungal growth on untreated and treated wallboard.

The photos in figure 3 illustrate the mold growth on an untreated control handsheet and the absence of mold growth on the handsheet treated with the bonded antimicrobial. Similar results have been realized when handsheets (treated and untreated) were mounted on drywall samples during the ASTM D3273 test.

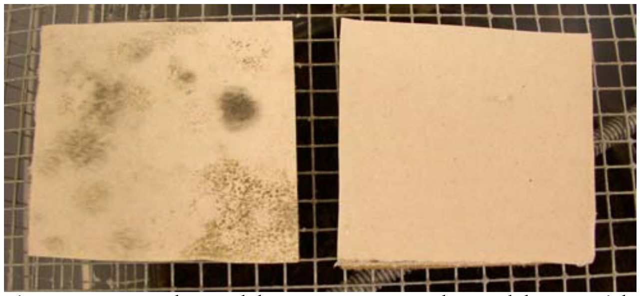

Fig 3. Untreated Handsheet   Treated Handsheets with bonded antimicrobial technology

Lab and Field Verification

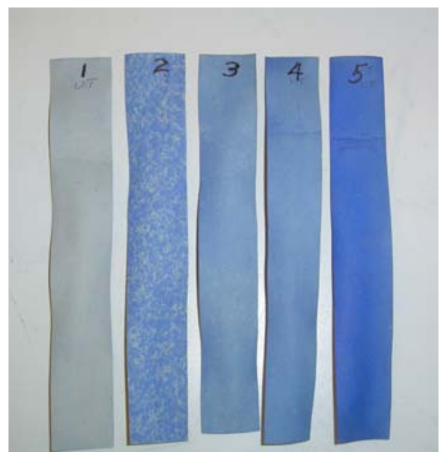

Fig. 4. BPB test results on wallboard paper.

With the silane quat, bonded antimicrobial, proper treatment levels for quality assurance can be verified in minutes in the lab, in the factory, on the job site, and post treatment.

The non-leaching, bonded antimicrobial is readily detected by staining the treated substrate with a water-soluble anionic dye, bromophenol blue—or BPB. The anion of the aqueous sodium salt of BPB complexes with the cation of the polymerized antimicrobial - resulting in a blue color on the treated substrate. An untreated substrate will retain its original color. The entire procedure takes only a few minutes and all you need is running water to perform the test.

Each sample will have variations of blue correlating to treatment levels. An increased level of treatment will result in a more intense color of blue. An extremely light shade of blue may indicate an under-treated sample, whereas a very intense blue may indicate over-treatment. (Fig 4)

Summary

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 and mildew on a wide array of consumer and commercial products.

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

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 cell wall 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 to which it is applied.

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.

Building and construction manufacturers that don't currently treat their products 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 "treatment with a future."

These manufacturers have a unique and valuable opportunity to position themselves in the construction products marketplace. Continued innovation with an antimicrobial treatment will undoubtedly bring a new generation of problem solving features to multiple niches in the construction products industry.

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