Antimicrobials in Building Materials

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Introduction

Microbes exist on every surface and environment that we encounter daily. These fascinating organisms outnumber us in every way. In fact, there are 10X more microbes living in and on us than human cells within our body. These invisible organisms play a key role in the success of our health and planet but with the good can come some bad.

The good Bacteria and fungal species constantly breakdown complex molecules into usable energy sources. This occurs when microbes degrade a fallen tree back into soil, it's carbon and nitrogen contents released back into the environment to be used by the next plant. Additionally, microbes play a key role in maintaining our health. These organisms are responsible for food digestion, mental health, and fighting off possible disease-causing microbes.

Most microbes found within their natural habit are carrying out routine processes that contribute to the environment. However, when these organisms are introduced into the body or human surroundings (ie buildings, clothes, food) there are consequences. These can lead to disease, food borne illness and degradation of materials.

The bad What happens when the microbes in your home and office begin to degrade the building materials? While the above scenarios result in a healthy body and environment, we want our buildings to be structurally sound and visibly pleasing for everyday use. The first signs that your materials are under microbial attack and being degraded are visible stains and odors. Ultimately this degradation can result in structural damage, decreased product integrity and shortened life span of the product.

Even before the stains and odors are apparent, microbes are present on surfaces. Studies have shown that many household surfaces can harbor bad bacteria (such as MRSA) for months[1]. Transmission from surface to hand will occur anytime an object is touched.

Product Deterioration: When and Why does it occur?

There are numerous products that are negatively impacted by microbial growth. Building products are of specific concern because of the investment required to install and maintain these items. Many of these products provide a hospitable environment for microbial attachment and serve as a food source for microbial growth. Examples of microbes thriving on building materials are given below.

Walls:

Wallboard: Fungal species, such as Aspergillus niger, Chaetomium, and Penicillium reproduce by spores[2]. The spores are carried in the air until they encounter a surface to colonize. Once on the surface, the spores will germinate, creating hyphal growth on the surface that results in a white “fuzzy” appearance. Eventually these hyphal species will create new spores that give the typical black, brown and green colors associated with fungal attack on wallboard materials. During this process, the fungus is using the wallboard as a food source, reducing the structural integrity of the material[3]. Wallboard is susceptible to fungal attack on two fronts. The internal portion of the wallboard is in contact with wood studs and insulation. The external portion is easily visible and is in constant contact with the homeowner.
The internal portion of wallboard, contained within the wall itself, not visible to the homeowner, can serve as an initial point of growth for fungus. Fungal growth within walls can begin to cause structural damage that isn’t immediately apparent and can spread throughout the house. The best way to protect the interior portion of the wallboard is to utilize antimicrobial treated products that prevent mold and mildew from growing[2].

Paint

On the exterior portion of the wallboard, paint can act as the first line of protection. The paint itself can serve as a barrier to fungal attack. In fact, some paints are specifically treated to prevent microbial growth in the paint can for increased shelf life of the liquid material[4]. In addition, fungal growth and attack on the exterior portion of the wallboard is easily seen and can be cleaned with sporicidal products such as bleach.

Insulation

Insulation can be generated from a number of different materials. The type of material utilized in buildings can range from cellulose, fiberglass, and foam to less common materials such as wool (https://energy.gov/energysaver/insulation-materials). Typically, insulation is exposed to high humidity, fluctuating temperatures and environmental air. These conditions create the perfect environment for microbial growth, specifically mold[5]. This growth of organisms within the insulation can serve as a reservoir for contaminating the air within the building itself[6]. Increased exposure to air borne fungal and bacterial organisms can cause increased risk for allergic reactions and negative health implications that are

1 Kramer, A., I. Schwebke, and G. Kampf, ***How long do nosocomial pathogens persist on inanimate surfaces? A systematic review.*** BMC infectious diseases, 2006. 6: p. 130.
2 Dedesko, S. and J.A. Siegel, ***Moisture parameters and fungal communities associated with gypsum drywall in buildings.*** Microbiome, 2015. 3(1): p. 71.
3 Andersson, M.A., et al., ***Bacteria, molds, and toxins in water-damaged building materials***. Appl Environ Microbiol, 1997. 62.
4 Page, K., M. Wilson, and I.P. Parkin, ***Antimicrobial surfaces and their potential in reducing the role of the inanimate environment in the incidence of hospital-acquired infections***. Journal of Materials Chemistry, 2009. 19(23): p. 3819-3831.
5 Gravesen, S., P.A. Nielsen, and R. Iversen, ***Microfungal contamination of damp buildings--examples of risk constructions and risk materials***. Environmental Health, 1999.
6 Oliveira, M., et al., ***Main airborne Ascomycota spores: characterization by culture, spore morphology, ribosomal DNA sequences and enzymatic analysis***. Applied microbiology and biotechnology, 2010. 86(4): p. 1171-81.

associated with Sick Building Syndrome (SBS) (https://www.ncbi.nlm.nih.gov/pubmed/19854820).

Bathrooms:

Grouts/sealants

High moisture content surrounding materials increases the susceptibility of these products to fungal attack[7]. Grouts and sealants are typically exposed to high moisture content, especially in bathroom areas. Much like the wallboard example above, fungal organisms such as Aspergillus, Penicillium, Chaetomium can reproduce using the grout as a food source. The discoloration that is typically seen with these species causes the homeowner to clean, however, the grout may be permanently damaged or stained based on the presence and outgrowth of these organisms. In some instances, the grout may even need to be replaced.

Bathroom sanitary ware

Cleaning and maintaining toilets is exhausting. Bacterial attachment to the toilet surface causes multiple stains that need to be removed. Toilet surfaces are perfect for the beginnings of microbial communities called biofilms. These biofilms are extremely hard to remove and will cause a surface to be stained very quickly even after it has been cleaned.

Changing stations

In public areas, baby-changing stations are rarely cleaned. These areas are exposed to dirty diapers and wipes consistently. Children and care takers typically touch the plastic components before, during and after a change. This creates a suitable environment for bacterial growth and transfer.

Faucets

When a toilet is flushed it creates aerosols that carry bacteria from the toilet bowl throughout the bathroom[8-9]. These can land on any surface, including sinks and floors. In addition to bacteria from each flush of the toilet, the faucet is one of the most touched surfaces within a bathroom. Once bacteria are on the faucet, each touch moves these bacteria from the faucet surface to the hands. It is important to clean all bathroom surfaces, including faucets with disinfectants to make sure that bacteria are routinely killed.

Living Area

Flooring

Based on a 2005 ABC report, the dirtiest surface in the bathroom is actually the floor, being continually inoculated with bacteria from the feet and shoes as well as toilet flushes (http://abcnews.go.com/2020/Health/story?id=1213831&page=1). This is true throughout a household or other building space. Many floors, from ceramic to carpet and hardwood, have crevices that allow for mold and bacterial growth. In general, bacteria on a floor is not a health concern but it can cause unnecessary and hard to remove odors. This is especially true if there is a pet in the house. Floors tend to retain some dirt that can serve as a food source for microbes, generating volatile organic compounds (VOCs) that we detect as odors around the house and building.

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7 Johansson, P., T. Svensson, and A. Ekstrand-Tobin, ***Validation of critical moisture conditions for mould growth on building materials***. Build Environ, 2013. 62.

8 David L. Johnson, K.R.M., Robert A. Lynch, Deborah V.L. Hirst, ***Lifting the lid on toilet plume aerosol: A literature review with suggestions for future research***. American Journal of Infection Control, 2013. 41: p. 254-258.

9 Barker, J. and M.V. Jones, ***The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet***. J Appl Microbiol, 2005. 99(2): p. 339-47.

Door Hardware

Door knobs and handles are amongst the most touched materials in buildings and houses. Gerba and others have shown that germs can spread from person to person through touching contaminated surfaces[10-11]. Additionally, Rheinbaben et.al. showed that contamination of doorknobs with a virus, lead to contamination of the hands of all study participants. Furthermore, the research demonstrated that transfer of the virus from the door knob to hands continued to occur even after multiple touches[12]. Keeping door hardware clean is important in maintaining a healthy lifestyle to prevent the spread of different microbes.

HVAC (Air filters)

Since spores and bacteria travel through the air it is important to have proper HVAC materials. Air filters play a large role in removing not only dust and dirt from the air in a building but also removing bacteria and mold[13]. Some air filters are even capable of killing these microorganisms thereby preventing growth and redistribution back into the air.

Kitchens:

Counters

Kitchen counters are the common surface throughout the kitchen that will be in contact with food and hands, and then cleaned (possibly with dirty sponges). Keeping the counter clean and free of microbes is important for good hygiene. Disinfection practices with food contact approved disinfectants should be routinely followed throughout the kitchen to prevent transmission of food borne pathogens[14].

While all of the above areas are subject to microbial attack and degradation, it is possible to prevent product deterioration, stains and odors via the use of embedded antimicrobial product protection. Embedded antimicrobials stop the outgrowth of stain and odor causing microorganisms and therefore help prevent the problems outlined above.

Antimicrobials: What are they?

There are multiple ways to prevent product deterioration, odors and stains caused by microbes. The first step should always be to clean surfaces with approved disinfectant materials that not only remove the odor and stain but also kill the underlying cause, microbes. In addition, embedded antimicrobials provide an another layer of security that the product itself is protected from microbial degradation. There are 3 types of antimicrobials that are sometimes confused and inappropriately interchanged. These three classes of antimicrobials have different end uses and microbial targets. The three classes of antimicrobials are:

1. Antibiotics: utilized for treating patients with microbial based infections.
2. Disinfection antimicrobials: antimicrobials utilized in liquid or wipe applications that deliver high kill rates quickly but provides discontinuous microbial reduction.

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10 Lopez, G.U., et al., ***Transfer efficiency of bacteria and viruses from porous and nonporous fomites to fingers under different relative humidity conditions***. Appl Environ Microbiol, 2013. 79(18): p. 5728-34.
11 Tamimi, A.H., S.L. Edmonds-Wilson, and C.P. Gerba, ***Use of a Hand Sanitizing Wipe for Reducing Risk of Viral Illness in the Home***. Food Environ Virol, 2015. 7(4): p. 354-8.
12 Rheinbaben, F., et al., ***Transmission of viruses via contact in ahousehold setting: experiments using bacteriophage straight phiX174 as a model virus***. J Hosp Infect, 2000. 46(1): p. 61-6.
13 Fröhlich-Nowoisky, J., et al., ***High diversity of fungi in air particulate matter***. Proceedings of the National Academy of Sciences of the United States of America, 2009. 106(31): p. 12814-9.
14 Rusin, P., P. Orosz-Coughlin, and C. Gerba, ***Reduction of faecal coliform, coliform and heterotrophic plate count bacteria in the household kitchen and bathroom by disinfection with hypochlorite cleaners***. Journal of Applied Microbiology, 1998. 85(5): p. 819-28.

3. Embedded antimicrobials: antimicrobials utilized for product preservation, odor control and the control of stain causing microorganisms and can offer continuous microbial reduction on a material.

Antibiotics

Antibiotics are governed by the Food and Drug Administration (FDA) and are meant solely for the treatment of humans with a microbial infection. These drugs target specific organisms in a manner that is proven to be safe for the human. There are numerous classes of antibiotics that target different species and parts of the microorganism. For example, penicillin based antibiotics target the ability of a microorganism to reproduce its cellular membrane but quinolones interact with the ability to reproduce DNA. Based on the infection, the doctor will prescribe the required antibiotic for treatment.

Disinfection antimicrobials

Disinfectants utilize antimicrobials that can reduce bacterial numbers quickly and are regulated via the Environmental Protection Agency (EPA). The EPA requires that disinfectants kill all claimed microbes within 10 minutes. Most disinfectant companies, such as Clorox and EcoLab, exceed the EPA expectations with label claims within 2 minutes or less. These disinfectants act very quickly but do not offer long lasting protection. Research has demonstrated that with traditional disinfectants the microbes on the surface reach initial levels within 2 to 6 hours[15].

Embedded Antimicrobials

It is not possible to clean every surface in a house or professional setting every 2-6 hours. The ability to provide continual microbial reduction can also be accomplished using articles with embedded antimicrobials[16-17]. In general, these surface treatments last the life-span of the product and provide a means to continuously control microbial burden on the surface.

Embedded antimicrobials can be incorporated into many household products such as grouts, flooring (including tiles, carpet, vinyl and wood products), polymeric materials (such as cutting boards), powder coated door handles, and textile based materials such athletic wear and shoes. All of these applications are found throughout our everyday environment and contribute to our quality of life.

Embedded antimicrobials are specifically designed to provide the needed protection for a specific end use. For example, a hospital bed rail may utilize an antimicrobial that targets bacteria to reduce inherent bacterial load on the surface but a grout will need an antimicrobial for mold to prevent discoloration of that surface. These antimicrobials reduce the bioburden on the surfaces without causing concern for negative health or environmental implications.

The utilization of these antimicrobial surfaces with good cleaning practices provides a systems-based approach to solving the problems associated with product deterioration, staining and odor development[4].

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15 Attaway, H.H., 3rd, et al., ***Intrinsic bacterial burden associated with intensive care unit hospital beds: effects of disinfection on population recovery and mitigation of potential infection risk***. Am J Infect Control, 2012. 40(10): p. 907-12.

16 Salgado, C.D., et al., ***Copper surfaces reduce the rate of healthcare-acquired infections in the intensive care unit***. Infect Control Hosp Epidemiol, 2013. 34(5): p. 479-86.

17 Schmidt, M.G., et al., ***Sustained reduction of microbial burden on common hospital surfaces through introduction of copper***. J Clin Microbiol, 2012. 50(7): p. 2217-23.

Embedded Antimicrobial Safety

The safety of antimicrobials is governed by the EPA and is broken into two main parts:

1. Antimicrobials that will be in contact with food and
2. Antimicrobials that will be non-food contact.

Once the use pattern, and food contact designation are determined, the safety of each pesticide is determined via a battery of tests that is specified through the Code of Federal Regulation[18][19]. At a minimum, each pesticide must pass a series of tests that target human health. These tests evaluate the ability of a pesticide to affect the skin, lungs, reproductive tract, and immune system. The pesticide is rated for each test and classified. Once classified a company must label products to indicate the associated hazard, if it exists. Based on the safety outcomes and the intended end uses, the EPA will review the appropriate use sites and then subsequently grant those to the company.

A company selling antimicrobials must operate within the provisions granted by the EPA. Embedded antimicrobials offer an additional safety in that the antimicrobial is encapsulated within the end product, reducing exposure rates to both the environment and the person.

The making and marketing of antimicrobial products is highly regulated by the EPA. There is a federal statute that specifically governs this area, the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). FIFRA allows the use of antimicrobials within products for product preservation, odor control and management of stains caused by bacteria and mold. Companies are not allowed to market products with health claims (i.e. will Kill 99.9% of MRSA). Companies are obliged to follow these statutes or risk fines.

The safety of some legacy antimicrobials has been called into question lately. Embedded antimicrobial companies are already replacing these antimicrobials, such as tin, arsenic and triclosan with greener more eco-friendly options that exist on the market. For this reason, working closely with a qualified provider is key to achieving successful integration of embedded antimicrobials into manufactured products.

Embedded Antimicrobial Efficacy:

The efficacy of antimicrobial products must be demonstrated pursuant to FIFRA. A company must ensure that its products are efficacious when utilized per label instructions. The company must also develop and maintain data demonstrating the efficacy of each end product to be in compliance with FIFRA. EPA can request the data at any point.

To prove the efficacy of antimicrobials, efficacy protocols have been developed by numerous international and national standards organizations including but not limited to:

1. International Standards Organization (ISO)
2. American Standards and Test Methods (ASTM)
3. American Association of Textile Colorist and Chemists (AATCC)
4. Japanese Embedded Standard (JIS)

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18 ***General Considerations for Uses of Antimicrobial Agents***, E.P. Agency, Editor. 2012: file:///C:/Users/gsloan/Downloads/EPA-HQ-OPPT-2009-0150-0019%20(1).pdf.

19 Office of Pesticide Programs, A.D., ***Applicability of the Treated Articles Exemption to Antimcirobial Pesticides***, P.R.N.P. 2000-1, Editor. March 6, 2000: https://www.epa.gov/pesticide-registration/prn-2000-1-applicability-treated-articles-exemption-antimicrobial-pesticides.

Protocols are developed with the input from numerous groups including companies, end users and consumers. The general standards are developed with input from subject matter experts. For standards dealing with microorganisms, microbiologists from academia and industry gather together to work through method development. Each group works strenuously to develop methods that are robust, reproducible, and representative of efficacy throughout use. These methods go through rigorous review cycles that take years to develop a final standard available for widespread use.

With the widespread adoption of antimicrobials in multiple industries, most organizations have a group dedicated to method development for antimicrobials specifically. It is through organizations like AATCC, ASTM and ISO, that there is effective self-policing throughout the industry. This is evident in peer-reviewed and approved test methods that allow reproducible demonstration of surface antimicrobial and product preservation attributes.

Efficacy is not solely attributable to one test that occurs immediately after manufacture. Once an antimicrobial is incorporated into an end use product, that product endures multiple tests for durability. Durability tests are associated with each end use. An antimicrobial for a textile application will be rated based on durability to home launderings with commercially available detergents. A cutting board application will have durability to dish washing, and scraping whereas a grout will be exposed to multiple rounds of moisture exposure. Outdoor applications are usually required to pass multiple rounds of intense UV exposure to ensure that the material is not affected and microbial efficacy is maintained.

Conclusions:

Embedded antimicrobials are a crucial way to control product deterioration, extend product life, and provide an additional layer of protection against microbial damage, odor, and stains. When combined with disinfectant technologies, there is a robust platform for cleaning and microbial control that can further extend product life.

Each article and item that is bought and placed into a home or professional space is an investment. Embedded antimicrobials ensure that the investment is well protected against the invisible.