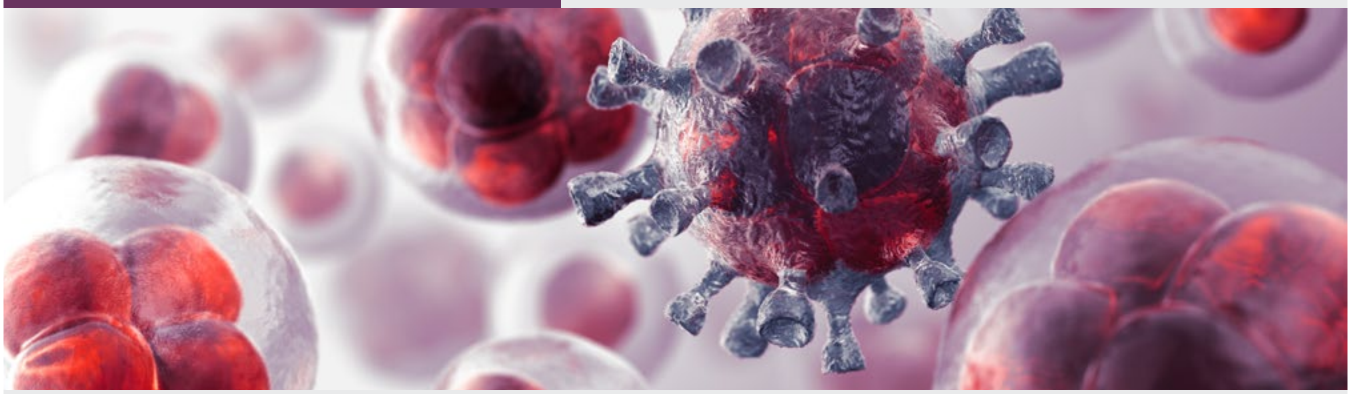
A PERKINS+WILL WHITE PAPER /



Healthy Environments: Understanding Antimicrobial Ingredients in Building Materials

MARCH 2017

Healthy Building Network

Perkins+Will

PERKINS+WILL

A PERKINS+WILL WHITE PAPER /

Understanding Antimicrobial Ingredients in Building Materials

Melissa Coffin, Operations Manager, Healthy Building Network

Tom Lent, Policy Director, Healthy Building Network

Susan Sabella, Chief Operations Officer, Healthy Building Network

Jim Vallette, Research Director, Healthy Building Network

Bill Walsh, Founder and President of the Board of Directors, Healthy Building Network

Mary Dickinson, Co-Director Materials Performance Lab and Regional Sustainable Design Leader, Perkins+Will

Suzanne Drake, Co-Director Materials Performance Lab, Senior Associate, Perkins+Will

Robin Guenther, Principal, Perkins+Will

Max Richter, Co-Director Materials Performance Lab, Associate, Perkins+Will

Brodie Stephens, General Counsel, Perkins+Will

ABOUT THE AUTHORS

As a research-driven architecture firm, Perkins+Will has created a practice where design, technology, and research converge to create places that improve how we live and work. To help keep us at the forefront of innovative design, we believe that it is essential to make focused investments in thought leadership in order to solve our clients' increasingly complex challenges and advance our profession. Toward that end, the Perkins+Will Science Fellow program was initiated in 2014. In 2015, in lieu of awarding an individual researcher the fellowship, the Healthy Building Network was engaged to aid our efforts to better understand the impacts our buildings have on human and environmental health.

The Healthy Building Network is a research-based not-for-profit organization focused on advancing the best environmental, health and social outcomes by reducing chemical hazards in the products that make up our built environment. The Pharos Project (a web-based building material evaluation system) and the Healthy Building News (since 2002) are just two means by which they have achieved deep respect within the design and construction industry. Perkins+Will and the Healthy Building Network possess many complementary synergies between our organizations, including core values around the Precautionary Principle, transparency, and optimism about the power of design to make positive change. The Science Fellowship program provided our organizations the perfect opportunity to see where those synergies could lead.

Special thanks to our peer reviewers

Caroline Cox, Director, Center for Environmental Health

Casey Johnson, Business Development Manager/ Sustainable Director North America, Forbo Flooring Systems

Jennifer MacDaniel, Project Principal, Kaiser Permanente

Dr. Ted Schettler, Science Director, Science and Environmental Health Network

Dr. David Walinga, Senior Health Officer, Natural Resources Defense Council

Table of Contents

A PERKINS+WILL WHITE PAPER /

Purpose Statement

The aims of this paper are to present current information about reported or potential health and environmental impacts of antimicrobial substances as commonly used within the building industry, and to assist architects, designers, building owners, tenants, and contractors in understanding those impacts. This paper is a compilation of information, and does not represent new research.

Perkins+Will strives to make use of this information to inform recommendations to each of our clients, based on their individual project needs. In general, when we find evidence of the potential for harm in the lifecycle of products that we specify, including to the environment, occupants, installers, fabricators, or factory workers, we prefer to proceed with caution in regard to the use of that product. Antimicrobials, as a class of chemicals, have been flagged in recent years as substances of concern, most recently in September 2016 when the Food and Drug Administration ruled that companies will no longer be able to market certain antibacterial washes that are currently in widespread use. We always work with our clients to find the best possible solutions for their project; sometimes, criteria other than health or environmental impacts (such as cost, availability, durability, or future maintenance, to name a few) drive the final decisions.

The purpose of this paper is to provide useful information for our colleagues and clients to consider in relation to the use of antimicrobials in the building industry. This paper summarizes our present thinking about the current use of antimicrobials in the building industry, and our current conclusion that they should be approached with skepticism and caution.

As in all matters regarding caution in relation to human and environmental health, we believe that the precautionary principle is appropriate as a tool for us to use in discussing design alternatives with our clients. Where there is information that credibly suggests the possibility of a negative human or environmental health impact in relation to a particular design choice, then we strive to advise our clients of that risk, and to see whether other alternatives exist.

The purpose of this paper is to provide useful information to our colleagues and clients to consider in relation to the use of antimicrobials in the building industry. This paper summarizes our present thinking about the current use of antimicrobials in the building industry, and our conclusion that they should be approached with skepticism and caution at this time.

Executive Summary

Building products incorporating antimicrobial additives are becoming increasingly prevalent. Paints, and other touchable surfaces such as countertops, and virtually any product considered as an interior finish may contain one or a combination of antimicrobials. These agents are considered pesticides, but their identity—and related hazards—can be difficult for the average person to discover. This lack of transparency creates a hurdle for the informed selection of products with reduced negative impacts.

No evidence yet exists to demonstrate that products intended for use in interior spaces that incorporate antimicrobial additives actually result in healthier populations. Further, antimicrobials may have negative impacts on both people and the environment.[1] Their widespread use may be associated with microbial resistance to these agents, and potentially to therapeutic antibiotics. Evidence is growing that antimicrobial additives can migrate from the products in which they are incorporated, finding their way into wastewater systems and the larger environment with unknown ecological implications, but with reasonable cause for concern.

Following the lead of the Centers for Disease Control and Prevention,[2] the Food and Drug Administration,[3] and other credible institutions,[4] Perkins+Will will be placing Products Marketed as Antimicrobial on its Precautionary List (transparency.perkinswill.com). Perkins+Will project teams should advise our clients of reasonable alternatives where appropriate.

Introduction

Antimicrobial substances are, by definition and design, substances that are toxic to certain organisms: bacteria, viruses, fungi, or protozoa—collectively known as microbes. Certain substances, nanoparticles, and metals can all be used as antimicrobials in everyday products, including those used to construct and finish buildings. However, because their purpose is to kill and control a target organism, antimicrobial additives are by definition pesticides,[5] and as such may impact our environment and our health beyond their intended purpose.

Words for the Wise

We use the term "antimicrobial" throughout this paper because it is commonly understood across audiences. But there are other terms used to describe these additives that you should be looking for during product selection.

Other terms you may come across that indicate an antimicrobial additive may be present include (but are not limited to):

- Anti-bacterial, Anti-fungal, and Anti-viral: used to describe antimicrobial substances targeted at a particular type of microbe
- Biocide or Biocidal
- Microbiocide, Microbiocidal, or Microbicidal
- Pesticide

Microbes are sometimes commonly referred to as "germs" because they can cause many familiar illnesses, such as the flu (the influenza virus) or athlete's foot (caused by the Trichophyton rubrum fungus). However, while people may associate microorganisms categorically with disease or unsanitary conditions, each microorganism is different. Not every microorganism can cause illness, and some, such as the microorganisms in our gut, are beneficial to human health.[6]

An increasing body of scientific evidence is demonstrating that widespread use of antimicrobials may have negative impacts on the environment,[7] and potentially on human health in the long term.[8] This growing evidence brings with it a renewed focus on whether the inclusion of antimicrobial substances into building products provides any positive health benefits to outweigh potential negative impacts.

As part of an effort to offer hospitals guidance on proper infection control, the Centers for Disease Control (CDC) reviewed the widespread use of products treated with antimicrobial additives in 2003. The agency concluded that even in hospitals, antimicrobial additives have not been proven to show a benefit to human health. The resulting guidance document, specifically for hospital use, states unequivocally that "no evidence is available to suggest that use of [products impregnated with antimicrobial additives] will make consumers and patients healthier or prevent disease. No data support the use of these items as part of a sound infection-control strategy."[9]

In September 2016 the Food and Drug Administration (FDA) concluded the most extensive review to date of data on the efficacy of antimicrobial additives in hand soaps and washes. After studying the issue for nearly 40 years,[10] the FDA determined that manufacturers have failed to show any evidence that these additives provide a benefit to human health.[11]

Antimicrobial additives used in building products are outside the jurisdictions of the CDC and the FDA because they are regulated by the US Environmental Protection Agency (EPA). However, this is merely a bureaucratic distinction. Available evidence supports the same conclusion drawn by the EPA's sister agencies: antimicrobials do not provide health benefits. When this lack of benefit is measured against the many costs of antimicrobials, it is clear that the best policy is to avoid products marketed as being antimicrobial whenever possible.

Consumers may feel a misplaced confidence in antimicrobial products, in part, because of confusing and in some instances misleading[12] marketing materials made possible by the extremely complex regulation governing antimicrobials in building products. The source of this confusion is that some products require an antimicrobial additive because it acts as a preservative, and claim no human health benefits. In other cases, even though a preservative only protects the product from decay or spoilage, the EPA's legal parameters allow antimicrobial products to be marketed in ways that consumers may interpret as providing a health benefit. For a more detailed discussion of preservatives and marketing claims, see **Appendix B**.

Available evidence supports the same conclusion drawn by the EPA's sister agencies: antimicrobials do not provide health benefits. When this lack of benefit is measured against the many costs of antimicrobials, it is clear that the best policy is to avoid products marketed as being antimicrobial whenever possible.

The Precautionary List: "Products Marketed As Antimicrobial"

A lack of transparency about which products include antimicrobials, and for what purpose, makes it very difficult to implement a list-based approach based on specific chemicals.

Further, trying to distinguish between products which are incorporating antimicrobials for legitimate preservation purposes from those that are making health claims (see **Appendix B**), or making misleading claims, requires a fair amount of time and expertise.

Because products which include antimicrobials for preservation purposes rarely advertise their inclusion, Perkins+Will design teams can avoid products using antimicrobials for any other purpose by simply avoiding products marketing themselves as antimicrobial.

Antimicrobials Become Mainstream

The availability of products with antimicrobial additives is a relatively new phenomenon. Consumer products is one example of the growth of antimicrobial products generally, with just a few dozen in 1994, to more than 2,000 in 2014.[13] The International Antimicrobial Council (IAC), a trade association for the industry, expects the global market for antimicrobial coatings to reach $4.5 billion by 2020. This estimate includes a large segment of coatings used in medical devices, but is also being driven by a growing US market for products aimed at improving indoor air quality. In 2013, 39% of antimicrobial coatings were sold in North America.[14] Table 1 provides a selection of antimicrobial additives commonly found in many types of building products.

*See **Appendix A** for information on the health and environmental hazards associated with each additive.*

A recent survey sponsored by makers of antimicrobials found "more than 60 percent of [consumers] polled indicated a very high concern about bacteria, parasites, dust, mold in the home and in food, as well as viral and airborne infections." These same respondents expressed an interest in expanding the use of antimicrobial additives to intimate items in their lives, including bedding and articles of clothing.[17] Another survey found that 89% of respondents were interested in purchasing antimicrobial countertops.[18]

Fueled by consumer interest, the inclusion of an antimicrobial additive has been positioned as a differentiator in the marketplace. For example, antimicrobial maker Microban lists a case study on its website where a manufacturer "looking for a way to innovate and differentiate from their competition" incorporated an antimicrobial ingredient into its engineered stone countertop product. The countertop company saw a 38% rise in annual revenue, and a 48% increase in market share.[19] Product literature boasts that this is the only countertop on the market with built-in antimicrobial protection, which battles odor-causing bacteria and stain-causing mildew.[20]

Table 1. Selection of Antimicrobials Found in Building Products[15]

Abbreviation, Antimicrobial, CAS No.	Used In
BBIT (2-Butyl-1,2-benzisothiazolin-3-one) CAS: 4299-07-4	Sealants, Adhesives, Caulks, Wallboard, Ceiling Tiles
BIT (1,2-Benzisothiazolin-3-one) CAS: 2634-33-5	Paints, Adhesive
Boric Acid CAS: 12179-04-3	Wood Products
CMIT or CIT (Methylchloroisothiazolinone) CAS: 26172-55-4	Paints/Stains, Adhesives, Caulks, Grout, Wood Products
Copper **CAS**: 7440-50-8	Knobs/Handles, Touchable Surfaces, Ceiling Tiles
CTAC (1-(3-chloroallyl)-3,5,7-triaza-1-azoniaadamantane chloride) CAS: 4080-31-3	Adhesives, Caulks, Grouts, Concrete Admixes, Paints
DCOIT (4,5-dichloro-2-octyl-2H-isothiazol-3-one) CAS: 64359-81-5	Caulks, Sealants, Grouts
DDAC (Alkyl didecyl dimethyl ammonium chloride) CAS: 7173-51-5	Wood Products
Elemental Silver / Silver Nanoparticles CAS: 7440-22-4	Upholstery & Fabrics, Hardware, Touchable Surfaces, Tile Installation Products, Ceramic Tile, Countertops, Adhesives, Sealants, Paints, Carpets, Textiles
Formaldehyde CAS: 50-00-0	Released into wet-applied products by certain preservative additives[16]
IPBC (3-iodo-2-propynyl butylcarbamate) CAS: 55406-53-6	Paints/Stains, Wire & Cable, Carpets, Textiles, Wood Products
MIT (Methylisothiazolinone) CAS: 2682-20-4	Paints/Stains, Adhesives, Caulks, Grout, Wood Products
OBPA (Oxybisphenooxyarsine) CAS: 58-36-6	Flexible PVC, Adhesives, Coatings, Textiles
OIT (2-n-octyl-4-isothiazolin-3-one) CAS: 26530-20-1	Adhesives, Textiles, Wood Products
Propiconazole CAS: 60207-90-1	Wood Products, Paints, Coatings, Caulks, Adhesives
QACs (Quaternary Ammonia Compounds) CAS: specific to individual substances	Disinfection Products, Wood Products, Specialty Paints
Silver Zeolite CAS: 130328-18-6	Paints, Carpet Fibers, Wallpaper, Adhesives, Fabrics/Textiles
Triclosan (2,4,4'-trichloro-2'- hydroxy-diphenyl-ether) CAS: 3380-34-5	Textiles, Plastic Sheets/Parts, Adhesives, Caulk, Coatings, Tile Installation Products, Hardware, Ceramic Tile, Carpets, Countertops
ZPT (Zinc pyrithione) CAS: 13463-41-7	Fabrics/Textiles, Wall Coverings, Adhesives, Caulks, Sealants, Grouts, Joint Compounds

ANTIMICROBIALS BECOME MAINSTREAM

Likewise, commercial door hardware is available with a coating impregnated with antimicrobial agents to give “peace of mind” in “areas where vigilance in the war against [microbes] is critical.”[21] This use has recognizable appeal as an application of antimicrobials, since a door knob is likely touched by many hands over the course of a day, and germs could be spread as a result. However, the antimicrobial additive functions as a preservative only, and its presence in the composition of the hardware can only protect the hardware itself from mold, mildew, and odor-causing bacteria.[22]

A similar application of antimicrobials can be seen with light switches and covers that are coated with an antimicrobial additive.[23] In one example, product literature promotes independent laboratory testing showing the additive is effective against bacteria such as the drug-resistant strain of staphylococcus commonly referred to as MRSA, while only briefly confirming elsewhere, in smaller text, that the antimicrobial additive is present only as a preservative that protects the switch and cover from mold, mildew, and other microbes that may jeopardize the “integrity of the product.”[24]

In all three of these instances, antimicrobials functioning as preservatives were added to building products to protect the product itself from attack by microbes. One could argue that in each of these examples, the typical consumer may have purchased the product assuming that their health may be improved or protected as a result. In fact, the Federal Trade Commission (the federal agency tasked with ensuring truth in advertising) warned the EPA of this very issue in 1994.[25]

*See **Appendix B** for more information on marketing claims.*

Likewise, commercial door hardware is available with a coating impregnated with antimicrobial agents to give “peace of mind” in “areas where vigilance in the war against [microbes] is critical.”

This opportunity for consumers to be confused about antimicrobials exists because of a lack of disclosure that antimicrobial ingredients are present, their specific identity, the purpose they serve in the product, and the potential health and environmental hazards they pose. In some instances, products will display an EPA registration number which can be searched for and found in the agency's online Pesticide Product Label System (PPLS) database.[26] Positive searches in the PPLS will retrieve the label for the antimicrobial ingredient in question and provide its identity. The label will also include the limitations of its efficacy, and a list of materials into which it can be incorporated. However, it can be nearly impossible to know when antimicrobials are present in a product as preservatvies, and in those cases, which antimicrobials are used.

In theory, several of the most popular disclosure tools in the building industry should allow researchers to determine if antimicrobials are used in a product.

- The Pharos Project database, Health Product Declaration, and the International Living Future Institute's Declare label program, all require that every intentional ingredient be itemized in order to earn full disclosure status.
- Safety Data Sheets (commonly referred to as SDS or MSDS sheets) only require disclosure of hazardous ingredients over 1% of the product composition, or .1% for ingredients with specific hazards.[27]

However, in practice these programs can miss antimicrobials added further up the supply chain, prior to their incorporation in the final product. For example, a preservative incorporated into a nylon carpet fiber might not be reported (or even known) by manufacturers using that fiber in an assembled carpet.[28] Further, Safety Data Sheets may not list antimicrobial ingredients if they are under the reporting thresholds and/or do not carry the specific hazards considered.

.

Costs to Human Health

Antimicrobials are by definition pesticides, and therefore can pose inherent hazards to human health and the environment.[29 30] **Appendix A** summarizes health hazards and typical applications of a number of antimicrobials that are used in building products; here, five antimicrobials with broad applications are explored in greater detail.

Triclosan

Triclosan (2,4,4'-trichloro-2'-hydroxy-diphenyl-ether, CAS #3380-34-5) is one of the antimicrobial additives subject to the FDA's 2016 ban in soaps and handwashes.[31] It is an antimicrobial effective against a broad spectrum of bacteria and fungi. It was first introduced to the market in 1964, and remains in use in large quantities today. Building products that may contain triclosan include countertops and table tops, textiles, and cementitious products such as concrete, mortar or grout.[32]

The Centers for Disease Control has stated that "the human health effects from exposure to low environmental levels of triclosan are unknown... More research is needed to assess the human health effects of exposure to triclosan."[33] Triclosan is part of a family of molecules called organohalides; other organohalides were used extensively as pesticides in the 1930s and 1940s before being banned or phased out over concern for their toxicity to humans and the environment.[34]

Triclosan is part of a family of molecules called organohalides; other organohalides were used extensively as pesticides in the 1930s and 1940s before being banned or phased out over concern for their toxicity to humans and the environment.

Silver Ions

Silver-impregnated zeolite and silver nanoparticles (nanosilver) are effective as antimicrobials because they release silver ions, which are lethal to target organisms. As silver reacts with oxygen (oxidizes) it releases ions (charged atomic particles) that kill bacteria and yeasts.[35] The antimicrobial properties of silver have long been known. Ancient writings describe the storage of food and water in silver containers to prevent spoilage.[36] The FDA approved the use of silver-based compounds for use in medical prevention of infection in the 1920s, and their use continues today in the healthcare sector.[37]

Silver ion coatings are increasingly used in hardware, switches, window treatments, cubicle curtains and textiles to provide antimicrobial properties. Silver-containing environmental surfaces and textiles in healthcare settings are promoted as products that may help reduce hospital-acquired infections by reducing microbial loads. Silver zeolites, glass-like structures of earthen particles and silver ions,[41] are a common antimicrobial compound used in hardware coatings in building construction and interior applications.[42]

Silver zeolite has not yet been classified for human health or environmental hazards by an authoritative agency. However, that may soon change. In 2014, The Swedish Chemicals Agency proposed that silver zinc zeolite be classified as a reproductive toxicant, after an assessment done as part of an ongoing review program presented reviewers with “a relatively clear cut case” that the substance could be harmful to reproductive health.[43] In the dossier prepared in support of silver zeolite’s reclassification, results of animal testing are cited as evidence that the substance should be considered a suspected carcinogen, an eye and skin irritant, capable of causing damage to unborn children, and capable of causing damage to internal organs.[44] If adopted, the classification as a reproductive toxicant would make silver zinc zeolite a banned substance under the European Union’s Biocidal Products Regulation.[45]

COSTS TO HUMAN HEALTH

What is Nanosilver?

What is true about elemental silver and silver-based compounds may not be true for nanosilver–extremely small silver particles measuring approximately one billionth of a meter. (For scale, note that a human hair is 100,000 nanometers wide.) At the nanoscale, materials begin to behave in ways that can be quite different from their conventionally-sized counterparts.

It is clear that nanosilver is an effective antimicrobial, but what is not clear is whether it is the inherent qualities of silver that make it effective, or whether the tiny size or shape of the particles is responsible. It could be both. In experiments with nanosilver particles and algae, researchers found that nanosilver is more effective than conventional silver at disrupting the photosynthesis of the algae, and at smaller doses. The study did not help the researchers understand exactly why this is, but one theory is that nanoparticles "act as a Trojan horse, entering a cell by bypassing its barriers to 'normal'-sized silver, and then releasing silver ions that damage cell machinery."[38]

A 2015 GreenScreen Assessment of nanosilver found it to be toxic to aquatic ecosystems, persistent in the environment, and hazardous to organ systems.[39]

Engineered nanoparticles as a class are still too new to be well understood. The National Institute for Environmental Health Sciences (NIEHS) reports that,

"While engineered nanomaterials provide great benefits, we know very little about the potential effects on human health and the environment.…Nano-sized particles can enter the human body through inhalation and ingestion and through the skin. Fibrous nanomaterials made of carbon have been shown to induce inflammation in the lungs in ways that are similar to asbestos."[40]

Despite a lack of understanding of their impacts, products made with these particles are already on the market and being used by consumers and the medical community for a host of purposes. The NIEHS, National Institute for Occupational Safety and Health, and Centers for Disease Control and Prevention are working collaboratively to assess the impacts of these materials through mathematical modeling and studies on live organisms.

Copper

Like silver, the antimicrobial properties of copper have been known for centuries, and like silver, it is the ions the metal releases that give it those properties. Its medical use as an agent of microbial control began after observing that those who worked with copper appeared to be immune from cholera during outbreaks in the 1800s. Laboratory testing has demonstrated that copper, and metal alloys containing copper, are effective against some bacteria, yeasts, and viruses.[46] The Copper Development Association, a trade association for copper manufacturers, has registered six copper alloys with the EPA to be used as antimicrobials in touch surfaces—railings, door hardware, etc.[47]

Copper can also be incorporated into polymers to provide an antimicrobial effect in non-metallic items.[48] Sanitaryware coatings containing copper claim to "suppress[es] the growth of algae, mold, mildew, fungi and bacteria which cause unpleasant odors, discoloration, staining, deterioration or corrosion."[49] Such coatings can be used on bathroom fixtures (for example a urinal in a public restroom) or in ceramic tiles.[50]

Researchers continue to study copper-based antimicrobials in laboratory settings to ascertain the limits to their applications. A 2016 Health Care Without Harm review of these studies concluded that, while copper alloy touch surfaces reduce microbial populations in lab tests, the only study yet to provide evidence that these surfaces result in reduced rates of infection has been disputed as showing "a low quality of evidence." Likewise, "the antimicrobial efficacy of textiles containing copper...can vary considerably and interpretation of results of laboratory testing is subjective."[51]

...while copper alloy touch surfaces reduce microbial populations in lab tests, the only study yet to provide evidence that these surfaces result in reduced rates of infection has been disputed as showing "a low quality of evidence."

COSTS TO HUMAN HEALTH

Quaternary Ammonia Compounds

Quaternary ammonia compounds (QACs) have been used in cleaning products since the 1930s and are effective against a broad spectrum of bacteria.[52] Still widely used as disinfectants in hospitals, QACs are organic (carbon-based) molecules that contain a positively charged nitrogen and are paired with a negatively charged halide or sulfide ion. This variability means there are many substances defined as a QAC, and that each substance has a unique antimicrobial effect. As a category, QACs are generally effective against bacteria, fungi, and certain viruses.[53] QACs can be found in building products, in wood preservatives,[54] or more recently, in specialty paint.[55]

The National Institutes of Health has designated QACs categorically as being asthmogenic (causing asthma, not just triggering an asthma attack), irritating (to eyes or skin), flammable and corrosive, harmful to aquatic ecosystems, and persistent in the environment. The agency also recommends that products with these ingredients not be used where antimicrobial protection is unnecessary.[56]

Formaldehyde donors

Some of the antimicrobials used as preservatives in wet-applied products can include “formaldehyde donors” or “formaldehyde releasers,” which are chemicals that decompose over time to release small amounts of formaldehyde into the product.[57] Formaldehyde has long been used as a preservative, perhaps most notably in tissue samples in laboratories.[58] Formaldehyde donors preserve wet-applied products by slowly releasing small amounts of formaldehyde into the product over time, increasing its shelf life.[59] CTAC (also known by the name Quaternium 15 or 1-(3-chloroallyl)-3,5,7-triaza-1-azoniaadamantane chloride) is a widely used formaldehyde-donor, for example.[60] There is some concern that use of such formaldehyde releasing preservatives (along with many other sources of exposure to formaldehyde) may be contributing to increased rates of formaldehyde sensitivity in the US population; however no direct link has yet been demonstrated.[61] While formaldehyde is also a recognized carcinogen,[62] the ability of small exposures to cause the disease has not been determined.[63]

Costs to Public Health

This widespread use of antimicrobials may be contributing to the emergence of microbes resistant to them, and more worryingly, resistant to some therapeutic antibiotics used in the healthcare system.

Antimicrobial resistance occurs when an antimicrobial agent is applied to a microbial population, but does not kill all of the organisms. The surviving organisms develop an immunity to the antimicrobial, and go on to reproduce and pass along this immunity.[64] "Through mutation, some of [the exposed microbes'] progeny emerge with resistance to the antibacterial agent aimed at it, and possibly to other antimicrobial agents as well."[65]

Antimicrobial resistant organisms are already being found for the additives discussed above. While not yet widely studied, antimicrobial resistance to silver-based additives has been reported in strains of Salmonella typhimurium, E. coli, and other bacteria, after exposure to antimicrobial silver in wound dressings.[66]

Microbes resistant to triclosan are also appearing. A recent study found the presence of triclosan in the body can actually promote Staph infections.[70] In laboratory experiments with E. coli, researchers were able to isolate organisms with low, medium, and high levels of resistance to triclosan. In one experiment, 100 times the concentration of triclosan was required to kill a resistant strain of E. coli as compared to a strain not yet exposed to the antimicrobial. These resistant E. coli also showed resistance to a new antibiotic being tested at the time of the experiment.[71]

Antimicrobial resistance occurs when an antimicrobial agent is applied to a microbial population, but does not kill all of the organisms.

COSTS TO PUBLIC HEALTH

What About the Financial Costs?

In its 2013 survey of consumers, the Dow Chemical Company found that, “consumers are willing to pay premiums of 5 to 20 percent for particular apparel and home furnishings items with... antimicrobial properties.”[67]

That price premium also exists in the building products sector. Kaiser Permanente cited the increased cost of antimicrobial products as part of its rationale for implementing a 2015 ban of antimicrobial building products.[68] Further, the cost of an antimicrobial paint used by a recent Perkins+Will client was nearly 160% higher than the cost of a standard paint.[69] This differential may be fairly inconsequential when used in small quantities, but will add up quickly when larger spaces are considered, and when the costs of regularly repainting with this more expensive product over time are factored in.

“Of major concern is the possibility that triclosan resistance may contribute to reduced susceptibility to clinically important antimicrobials, due to either cross-resistance or co-resistance mechanisms. Although the number of studies elucidating the association between triclosan resistance and resistance to other antimicrobials in clinical isolates has been limited, recent laboratory studies have confirmed the potential for such a link in Escherichia coli and Salmonella enterica. Thus, widespread use of triclosan may represent a potential public health risk in regard to development of concomitant resistance to clinically important antimicrobials.”[72]

Quaternary ammonia compounds (QACs) may also cause antimicrobial resistance when used improperly. In a 2012 study, researchers exposed E. coli bacteria to increasing concentrations of three different types of QACs for seven days. They found that regardless of which QAC was used, the exposures led to E. coli populations that had become resistant to several families of antibiotics. The authors warn that use of QACs in too small of doses “may lead to the emergence of antibiotic-resistant bacteria and may represent a public health risk.”[73] A 2004 article coauthored by consumer product giant Procter & Gamble warned, “The use of QACs in the home will expose a wide range of environmental and potentially pathogenic bacteria to these antimicrobials, often at sublethal concentrations, making the home a potentially high-risk environment for resistance selection.”[74] A new wall paint on the market, with television advertising aimed at the general public highlighting its continuous protection against bacteria, contains QACs.[75]

Costs to Environmental Health

If antimicrobials stayed put in the products incorporating them, the costs of using antimicrobials may end with human and public health impacts. But they don't—evidence is mounting that antimicrobial additives leach out of their host products, ultimately finding their way into the general environment. This is of particular concern with nano-scale antimicrobials.

A recent report by the National Institute of Standards and Technology (NIST) found that nanoparticles can migrate from flooring finishes and indoor paints after cleaning, and can be present in interior spaces. The report includes a particular caution with regard to small children who may crawl on such floors, presenting greater opportunity for exposure to these particles. It also cites a lack of data about how these particles are released, accumulate, and move within spaces as a barrier to providing a more complete health assessment.[76]

There is additional evidence that silver-based antimicrobials can leach out of the materials in which they are incorporated and find their way into the environment. The Swedish Chemicals Agency tested articles of clothing treated with silver antimicrobials and found that, while the percentage of silver lost after washing did vary, leaching was common. In at least one case, 98% of the antimicrobial silver was lost over ten washes.[77] These silver particles wash down drains and enter water treatment facilities. Wastewater treatment sludge is sometimes spread as crop fertilizer or used in landscaping, where they enter the surrounding ecosystem.[78] As noted above, nanosilver is considered toxic to aquatic ecosystems, persistent in the environment, and hazardous to organ systems.[79]

The Swedish Chemical Inspectorate noted as part of its textile study that silver concentrations in sewage sludge in Sweden had been on the decline since the photography industry moved away from chemical development, but that silver concentrations are starting to accumulate once more: "The fact that levels of silver are no longer declining in the sludge is assumed to be due to increased use of silver as [an antimicrobial additive] in various articles."[80]

If antimicrobials stayed put in the products incorporating them, the costs of using antimicrobials may end with human and public health impacts. But they don't—evidence is mounting that antimicrobial additives leach out of their host products, ultimately finding their way into the greater environment.

COSTS TO ENVIRONMENTAL HEALTH

By the late 1970s, researchers were finding triclosan contamination in river water and sediments, and in 2002 the US Geological Survey named triclosan as one of the most frequently found contaminants in waterways sampled across 30 states.[81 82] In a summary of literature available in 2014, one researcher writes:

> *[Triclosan] has been detected in drinking water resources, 75% of urine samples representative of the U.S. population, 97% of representative U.S. breast milk samples, and combined [triclosan and related compound triclocarban] constitute over 60% of the total mass of 96 pharmaceuticals detectable in municipal sludge using EPA Method 1694. Indeed, the environmental ubiquity of both chemicals has escalated such that [triclosan, related antimicrobial triclocarban used in cosmetics,] or both compounds are now detectable in house dust worldwide, in ocean water, and locations as remote as the water loop of spacecraft."*[83]

The global distribution of triclosan raises concern. It is persistent and bioaccumulative—meaning that it will not break down rapidly in the environment and will increase in concentration as it moves up the food chain, is very toxic to aquatic environments, and has known endocrine activity.[84]

In a collision of unintended consequences, a recent study found triclosan-resistant bacteria in the sediments of waterways, and indications that the presence of triclosan may result in a less diverse aquatic ecosystem, with fewer algae available to support an underwater food chain.[85]

*See **Appendix A** for more detailed information on the environmental hazards posed by antimicrobials used in building products.*

In a collision of unintended consequences, a recent study found triclosan-resistant bacteria in the sediments of waterways, and indications that the presence of triclosan may result in a less diverse aquatic ecosystem, with fewer algae available to support an underwater food chain.

Antimicrobials in Healthcare Facilities

One sector where the use of antimicrobial building products may be especially tempting is healthcare. In addition to their primary purpose of restoring patients to health, hospitals must also combat the spread of hospital-acquired infections (HAIs) such as pneumonia, urinary tract infections,[86] or drug-resistant staphylococcus (MRSA). These serious infections can be lethal.[87] An estimated one in 25 hospital patients is infected with at least one HAI at any given time in an American hospital.[88]

Despite the CDC's 2003 infection control guidance to the contrary, many Perkins+Will healthcare clients do look to antimicrobial interior finishes and fabrics as a tool in preventing HAIs. Perkins+Will has identified the following as common factors driving this interest:

Treating patients with HAIs is expensive and hospitals may not be reimbursed.
In 2009, the CDC estimated that direct medical care needed to treat hospital-associated infections cost as much as $33 billion annually.[89] Historically, hospitals have been compensated for these additional costs by insurance and other programs meaning that, while HAIs were certainly an unwanted outcome following a medical procedure, the hospital did not feel a financial pressure to lower the rates of HAIs. However, recent changes to Medicare and provisions under the Affordable Care Act mean hospitals are increasingly left to cover the costs of treating HAIs.[90]

Patients can look up HAI rates and avoid hospitals with more frequent infections.
The Centers for Medicare and Medicaid Services created a website to make rates of HAIs and other information about the quality of hospitals publicly available. Where rates of HAIs were previously unknown to patients,[91] this website creates another pressure point for hospitals to reduce their rates of HAIs in order to remain competitive.

Hospitals fear lawsuits after patients contract HAIs.
Regardless of how prevalent HAIs may be in a given hospital, every case leaves the hospital vulnerable to a potential lawsuit on the grounds that the hospital was negligent in preventing the infection.[92] Hospitals carry insurance to protect them from these liabilities,[93] and may therefore also face pressure from their insurer to bring rates of HAIs to as close to zero as possible.

An estimated 1 in 25 hospital patients is infected with at least one HAI at any given time in an American hospital.

Hospitals Are Not Immune to Confusing Antimicrobial Marketing

In 2014 a Florida hospital announced that they had replaced the conventional scrubs worn by hospital staff in favor of new scrubs, made from a fabric advertised as repellent to liquids and providing antimicrobial protection against bacteria contributing to HAIs.[94]

However, these claims appear to be based on a single study of these garments, sponsored by their manufacturer. Researchers reported that the treated scrubs reduced the level of MRSA organisms found on the fabric at the end of day as compared to conventional scrubs, but had no effect on vancomycin-resistant enterococci (VRE) or gram-negative rod bacteria. The study concluded that further research is needed to discover whether or not garments of this type could be beneficial in reducing HAI rates in hospitals.[95] The study did not address the potential for the materials in these garments to contribute to antimicrobial resistance.

The study reveals that an antimicrobial additive used in the scrubs is based on quaternary ammonia; however, the specific substance is not disclosed, and the Environmental Protection Agency lists no FIFRA registrations for the company making the scrubs. This suggests that the manufacturer has not supplied efficacy data to the agency in support of a health claim.

*See **Appendix B** for more on manufacturer responsibilities with regard to marketing claims.*

When working with healthcare clients, Perkins+Will seeks to remind those who are interested in installing antimicrobial products in their buildings that, despite the pressures they may be facing, there continues to be no evidence that these products have any impact on the rate of HAI occurrence or transmission. Further, the CDC's guidance on infection control protocols states that, even in the case of patients with compromised immune systems, the health of all patients is best ensured through proper cleaning practices and maintenance of building engineering systems (ventilation, etc.).[96]

In fact, hospitals are successfully reducing their rates of HAIs without the use of these products. Kaiser Permanente hospitals, for example, receive the highest possible scores for hospital safety,[97] due in part to their comprehensive approach to controlling these infections. This approach focuses on hand hygiene and educational materials geared toward staff.[98] As previously noted, Kaiser recently instituted a ban of building products containing certain antimicrobial additives, offering further evidence that these substances are not needed to successfully combat HAIs.

A 2016 publication by Health Care Without Harm concludes, "While antimicrobials in hospital furnishings may ultimately prove to be efficacious, currently the benefits, risks, tradeoffs, and costs associated with their use are largely unknown." The authors found that "the growing use of products containing antimicrobials can also further increase the risk of antibiotic resistance, engender a false sense of security with reduced attention to cleaning and disinfection, and increase costs of products and materials."[99]

Kaiser Permanente hospitals, for example, receive the highest possible scores for hospital safety, due in part to their comprehensive approach to controlling these infections.

Avoiding Antimicrobials in Practice

The primary challenge to avoiding antimicrobials in building products is a lack of transparency. Particularly with regard to antimicrobial preservatives, it can be nearly impossible to discover which products contain these additives, and which additives are used.

Until there is better disclosure, the most foolproof approach to avoiding antimicrobials is to avoid products marketing this attribute.

But architects and designers can also be proactive about finding antimicrobial-free materials and finishes. Some manufacturers have eliminated antimicrobials from some or all of their product lines. Design teams should prefer these products whenever possible.

While there is currently no certification a product can earn verifying a lack of antimicrobials, third parties can be a reference when selecting materials. For example, the Healthy Hospitals Healthy Interiors initiative maintains a list of furniture manufacturers stating that their products are free of the specific antimicrobials triclosan and triclocarban.[100] Contacting these manufacturers—or manufacturers of any product considered for a building project—to discover if antimicrobial-free options are available is a good practice.

Another resource for architects and designers is the Pharos Project, which identifies the common composition of more than 100 products used in building construction and finishing. These “Common Product Profiles” identify when the inclusion of antimicrobial substances is a standard practice in a given product type.[101]

Conclusion

In 2003 the Centers for Disease Control and Prevention reviewed the data and concluded there was no evidence that antimicrobial additives provided a benefit, even in a hospital setting. In 2016, after studying the issue for four decades, the Food and Drug Administration came to the same conclusion: there is no evidence that antimicrobial additives provide an added benefit. If one scrutinizes carefully manufacturer claims and marketing, even in the healthcare setting, one finds no field studies, and no claims that antimicrobial products reduce the need for infection control measures.

Potential impacts to human and environmental health as a result of these additives may include antibiotic resistance, and the appearance of antimicrobial additives in ecosystems. Because of this, project teams should be made aware when antimicrobial products are suggested, or when antimicrobial additives are found in any product specification. If the antimicrobial functionality is optional, review the benefits and potential risks with the client—opting out may be the best course.

Ideally, manufacturers would clearly disclose when antimicrobials are added to building products, the specific additives used, and their purpose within the product. Until this is standard practice, the designer's best course of action is to educate clients interested in antimicrobial products, and explain why they may want to be avoided.

Perkins+Will's Transparency Site is being updated with a Watch List—substances of concern that are generally unavoidable at this point in time. Antimicrobials, as a group, will be added to this classification. In addition, the Precautionary List itself will soon include Products Marketed as Antimicrobial, reflecting the position of the CDC, the FDA, and other credible organizations that have reviewed the state of evidence on these substances and found them to be unnecessary. The growing inclusion of antimicrobial additives is at odds with the firm's commitment to the health and wellbeing of people and planet, and with the precautionary principle, which is an integral part of the firm's approach to product evaluation.

Ultimately, the decision to include these products in projects is at the discretion of our clients. The intentional use of antimicrobials in building products beyond what might be required for product preservation, in our opinion, should be avoided. Many of our clients request antimicrobial qualities for products we select; as trusted advisors to our clients, it is our responsibility to provide information regarding the pitfalls of antimicrobials and lack of proven benefit of their use in practice.

In 2016, after studying the issue for four decades, the Food and Drug Administration came to the same conclusion: there is no evidence that antimicrobial additives provide an added benefit.

Endnotes

1 For a list of hazards associated with a selection of antimicrobial substances, see Appendix A.

2 "Guidelines for Environmental Infection Control in Health-Care Facilities." Centers for Disease Control and Prevention, 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_HCF_03.pdf

3 US Food and Drug Administration. "FDA Issues Final Rule on Safety and Effectiveness of Antibacterial Soaps." FDA News Release, September 2, 2016. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm517478.htm

4 See for example, Kaiser Permanente. "Press Release: Kaiser Permanente Rejects Antimicrobials for Infection Control," December 11, 2015. https://share.kaiserpermanente.org/article/kaiser-permanente-rejects-antimicrobials-for-infection-control/

5 US Environmental Protection Agency, OARM. "Pesticides' Impact on Indoor Air Quality." Overviews and Factsheets. Accessed March 29, 2016. https://www.epa.gov/indoor-air-quality-iaq/pesticides-impact-indoor-air-quality

6 US Department of Health & Human Services. "Understanding Microbes in Sickness and in Health." National Institute of Allergy and Infectious Diseases, September 2009 (3).

7 "Antibacterial Substances Leaking out with Washing Water - Analysis of Silver, Triclosan and Triclocarban in Textiles before and after Washing." Swedish Chemicals Agency, February 2012. https://www.kemi.se/global/pm/2012/pm-1-12-antibact-en.pdf; Halden, Rolf "On the Need and Speed of Regulating Triclosan and Triclocarban in the United States." Environmental Science & Technology 48 (March 3, 2014): 3603–11.

8 See for example, Yazdankhah, Siamak P., Anne A. Scheie, E. Arne Høiby, Bjørn-Tore Lunestad, Even Heir, Tor Øystein Fotland, Kristine Naterstad, and Hilde Kruse. "Triclosan and Antimicrobial Resistance in Bacteria: An Overview." Microbial Drug Resistance (Larchmont, N.Y.) 12, no. 2 (2006): 83–90. doi:10.1089/mdr.2006.12.83;McBain, Andrew J., Ruth G. Ledder, Louise E. Moore, Carl E. Catrenich, and Peter Gilbert. "Effects of Quaternary-Ammonium-Based Formulations on Bacterial Community Dynamics and Antimicrobial Susceptibility." Applied and Environmental Microbiology 70, no. 6 (June 1, 2004): 3449–56. doi:10.1128/AEM.70.6.3449-3456.2004; Scientific Committee on Emerging and Newly Identified Health Risks. "Assessment of the Antibiotic Resistance Effects of Biocides." European Commission, January 19, 2009. http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_021.pdf

9 U.S. Department of Health and Human Services Centers for Disease Control and Prevention (CDC). "Guidelines for Environmental Infection Control in Health-Care Facilities." Centers for Disease Control and Prevention, 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_HCF_03.pdf

10 Greenfield, Nicole. "The Dirt on Antibacterial Soaps." NRDC, March 15, 2016. https://www.nrdc.org/stories/dirt-antibacterial-soaps

11 US Food and Drug Administration. "FDA Issues Final Rule on Safety and Effectiveness of Antibacterial Soaps." FDA News Release, September 2, 2016. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm517478.htm

12 See for example, "FTC Charges Companies with 'Bamboo-Zling' Consumers with False Product Claims | Federal Trade Commission." Accessed March 30, 2016. https://www.ftc.gov/news-events/press-releases/2009/08/ftc-charges-companies-bamboo-zling-consumers-false-product-claims "Press Release: 'The North Face' Parent Company, 'Saniguard' Marketers, and Califone Fined More Than $500,000 Over Antimicrobial Claims." Accessed March 29, 2016. https://yosemite.epa.gov/opa/admpress.nsf/0/AC0C1AF1625888608525771B00561E83

13 Halden, Rolf. "On the Need and Speed of Regulating Triclosan and Triclocarban in the United States." Environmental Science & Technology 48 (March 3, 2014): 3603–11.

14 International Antimicrobial Council. "Antimicrobial Coatings Market Expected To Reach $4,520.3 Million by 2020." International Antimicrobial Council, August 10, 2015. http://amcouncil.org/antimicrobial-coatings-market-expected-to-reach-4520-3-million-by-2020/

15 Excerpted from Appendix A. See Appendix for sourcing.

16 See for example, THOR Specialties, Inc. "Biocides." Accessed March 29, 2016. http://www.thor.com/usa/biocides.html

17 Dow Chemical Company. "Increasing Consumer Interest in Personal and Family Wellness Creates Potential Sales Growth Opportunities for Apparel, Footwear and Home Furnishings Treated with Next-Generation Antimicrobials," September 10, 2013. http://www.dow.com/microbial/news/2013/20130910a.htm

18 Microban International. "Progressive Antimicrobial Countertop Product Protection." Accessed March 28, 2016. http://www.microban.com/what-we-do/by-product/categories/countertops

19 Microban International. "Silestone Case Study." Accessed March 29, 2016. http://www.microban.com/about-microban/case-studies/silestone-case-study

20 Cosentino. "Silestone USA Bacteriostatic Protection." Accessed March 25, 2016. http://www.silestoneusa.com/what-is-silestone/bacteriostatic-protection/

21 See for example, SARGENT Manufacturing Company. "A Whole New Kind of Building Security." Accessed March 29, 2016. http://www.sargentlock.com/solutions/microshield/

22 See for example, "US Environmental Protection Agency. "Agion Silver Antimicrobial Type AL Label," October 7, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/088165-00002-20141007.pdf

23 See for example, "Leviton Manufacturing Co. "Antimicrobial Treated Devices." Accessed March 28, 2016. http://www.leviton.com/OA_HTML/SectionDisplay.jsp?section=66321&minisite=10251

24 Leviton Manufacturing Co., Inc. "Antimicrobial Treated Devices from Leviton," 2014. http://www.leviton.com/OA_HTML/ibcGetAttachment.jsp?cItemId=9SsCO-7Ck1nFi0WOCbfU3g&label=IBE&appName=IBE&LEVCOMP_pses=ZG823CD6CD65D6C2489460ED2083C88A81F1F11FDF76242E07E35629C19E119CA10E6C19D24487FA4B8DBC089655CC8D5199BE0165DAD1F3D8&minisite=10251

25 Peeler, C. Lee. "Public Information and Records Integrity Branch Information Resources and Services Division Office of Pestcide Programs," July 17, 1998. https://www.ftc.gov/sites/default/files/documents/advocacy_documents/ftc-staff-comment-environmental-protection-agency-concerning-treated-articles-exemption-under-epas/v980017.pdf

26 US Environmental Protection Agency. "Pesticide Product Label System." Database. Accessed March 29, 2016. https://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1

27 Heine, Lauren, Matteo Kausch, Susan Klosterhaus, Stacy Glass, and Tom Lent. "Material Health Evaluation Programs - Harmonization Opportunities," August 20, 2013. http://www.usgbc.org/resources/material-health-evaluation-programs-harmonization-opportunities

28 See for example, NSF Sustainability. "Health Product Declaration." NSF Sustainability. Accessed March 30, 2016. http://www.nsf.org/newsroom_pdf/su_health_product_declaration.pdf

29 US Environmental Protection Agency, OARM. "Pesticides' Impact on Indoor Air Quality." Overviews and Factsheets. Accessed March 29, 2016. https://www.epa.gov/indoor-air-quality-iaq/pesticides-impact-indoor-air-quality

30 US Environmental Protection Agency, OCSPP. "About Pesticide Registration." Overviews and Factsheets. Accessed August 1, 2016. https://www.epa.gov/pesticide-registration/about-pesticide-registration

31 US Food and Drug Administration. "FDA Issues Final Rule on Safety and Effectiveness of Antibacterial Soaps." FDA News Release, September 2, 2016. http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm517478.htm

32 Like many chemicals, Triclosan has many synonyms. 5-CHLORO-2-(2,4-DICHLOROPHENOXY)PHENOL is the one referenced in literature submitted to the Environmental Protection Agency for the product sold under the brand Sanitized. See US Environmental Protection Agency. "Sanitized Brand PLA," July 25, 2011. https://www3.epa.gov/pesticides/chem_search/ppls/003090-00215-20110725.pdf

33 Centers for Disease Control and Prevention. "Triclosan FactSheet," November 2009. http://www.cdc.gov/biomonitoring/pdf/Triclosan_FactSheet.pdf

34 Halden, Rolf. "On the Need and Speed of Regulating Triclosan and Triclocarban in the United States." Environmental Science & Technology 48 (March 3, 2014): 3603–11.

35 Phys.org. "Some Antibacterials Come with Worrisome Silver Lining," February 24, 2014. http://phys.org/news/2014-02-antibacterials-worrisome-silver-lining.html

36 Clement, Julia L., and Penelope S. Jarrett. "Antibacterial Silver." Metal-Based Drugs 1, no. 5–6 (1994): 467–82. doi:10.1155/MBD.1994.467.

37 Chopra, Ian. "The Increasing Use of Silver-Based Products as Antimicrobial Agents: A Useful Development or a Cause for Concern?" Journal of Antimicrobial Chemotherapy 59, no. 4 (April 1, 2007): 587–90. doi:10.1093/jac/dkm006.

38 Lubick, Naomi. "Nanosilver Toxicity: Ions, Nanoparticles - or Both?" Environmental Science & Technology, October 1, 2008, 8617.

39 Linde, Nancy. "Chemical Hazard Assessment for Nanosilver, Metallic (CAS# 7440-22-4) [Modified from GreenScreen Version 1.2]." NSF International, October 31, 2015. https://pharosproject.net/uploads/files/gs/67ee53dd37dd3b0691b37ee19797acae5622d4ba.pdf

40 National Institute of, and Environmental Health Sciences. "Nanomaterials." Accessed March 29, 2016. http://www.niehs.nih.gov/health/topics/agents/sya-nano/

41 Matsumura, Yoshinobu, Kuniaki Yoshikata, Shin-ichi Kunisaki, and Tetsuaki Tsuchido. "Mode of Bactericidal Action of Silver Zeolite and Its Comparison with That of Silver Nitrate." Applied and Environmental Microbiology 69, no. 7 (July 2003): 4278–81. doi:10.1128/AEM.69.7.4278-4281.2003.

42 BASF Corporation. "Irgaguard B 5000 Silver-Zinc Zeolite," June 2012. https://pharosproject.net/uploads/files/sources/1828/1397591706.pdf

43 Chemical Watch Biocides Hub. "Sweden Proposes Reprotox Classification for Silver Zinc Zeolite." BiocidesHub, August 14, 2014. https://chemicalwatch.com/biocideshub/20878/sweden-proposes-reprotox-classification-for-silver-zinc-zeolite

44 Swedish Chemicals Agency. "CLH Report for Silver Zinc Zeolite," April 13, 2015. https://echa.europa.eu/documents/10162/2dfc3e57-5cd1-4bf1-b87e-e28792faab49

45 Chemical Watch Biocides Hub. "Sweden Proposes Reprotox Classification for Silver Zinc Zeolite." BiocidesHub, August 14, 2014. https://chemicalwatch.com/biocideshub/20878/sweden-proposes-reprotox-classification-for-silver-zinc-zeolite

46 Grass, Gregor, Christopher Rensing, and Marc Solioz. "Metallic Copper as an Antimicrobial Surface." Applied and Environmental Microbiology 77, no. 5 (March 2011): 1541–47. doi:10.1128/AEM.02766-10.

47 See for example, US Environmental Protection Agency. "Antimicrobial Copper Alloys - Group I and Associated Fabricated Products Master Label," August 26, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/082012-00001-20140826.pdf

48 US Environmental Protection Agency. "Agion Silver Antimicrobial Type AL Label," October 7, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/088165-00002-20141007.pdf

49 US Environmental Protection Agency. "Notice of Pesticide Registration, A-Liquid," November 5, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/088751-00001-20141105.pdf

50 TOTO. "Hydrotect." Accessed August 3, 2016. http://gb.toto.com/technology/technology-single-view/Technology/show/HYDROTECT/

51 Schettler, Ted. "Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections?" Health Care Without Harm. Accessed March 30, 2016. https://noharm-uscanada.org/sites/default/files/documents-files/3854/Antimicrobials%20Report%202016_0.pdf

52 McBain, Andrew J., Ruth G. Ledder, Louise E. Moore, Carl E. Catrenich, and Peter Gilbert. "Effects of Quaternary-Ammonium-Based Formulations on Bacterial Community Dynamics and Antimicrobial Susceptibility." Applied and Environmental Microbiology 70, no. 6 (June 1, 2004): 3449–56. doi:10.1128/AEM.70.6.3449-3456.2004.

53 Rutala, William, David Weber, and Healthcare Infection Control Practices Advisory Committee (HICPAC). "Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008." Centers for Disease Control and Prevention. Accessed August 3, 2016. http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection_Nov_2008.pdf

54 National Institutes of Health. "Quaternary Ammonium Compounds (QACs or Quats)." Accessed August 3, 2016. https://nems.nih.gov/soc/Pages/Quaternary-Ammonium-Compounds-(QACs-or-Quats).aspx

55 US Environmental Protection Agency. "Sanitizer #1 Notice of Pesticide Registration," October 8, 2015. https://www3.epa.gov/pesticides/chem_search/ppls/067603-00013-20151008.pdf

56 National Institutes of Health. "Quaternary Ammonium Compounds (QACs or Quats)." Accessed August 3, 2016. https://nems.nih.gov/soc/Pages/Quaternary-Ammonium-Compounds-(QACs-or-Quats).aspx

57 See for example, THOR Specialties, Inc. "Biocides." Accessed March 29, 2016. http://www.thor.com/usa/biocides.html

58 Thavarajah, Rooban, Vidya Kazhiyur Mudimbaimannar, Joshua Elizabeth, Umadevi Krishnamohan Rao, and Kannan Ranganathan. "Chemical and Physical Basics of Routine Formaldehyde Fixation." Journal of Oral and Maxillofacial Pathology : JOMFP 16, no. 3 (2012): 400–405. doi:10.4103/0973-029X.102496.

59 Unilever. "Formaldehyde Donors." Accessed August 3, 2016. https://www.unilever.com/about/innovation/Our-products-and-ingredients/Your-ingredient-questions-answered/Formaldehyde-donors.html

60 European Commission Scientific Committee on Consumer Safety. "Opinion On Quaternium-15." Scientific Committee on Consumer Safety, December 13, 2011. http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_077.pdf

Endnotes

61 Anton C de Groot, Mari-Ann Flyvholm. "Formaldehyde-Releasers: Relationship to Formaldehyde Contact Allergy. Contact Allergy to Formaldehyde and Inventory of Formaldehyde-Releasers." Contact Dermatitis 61, no. 2 (2009): 63–85. doi:10.1111/j.1600-0536.2009.01582.x.

62 International Agency for Research on Cancer. "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans." Accessed August 3, 2016. https://monographs.iarc.fr/ENG/Classification/index.php

63 American Cancer Society. "Formaldehyde." Accessed August 3, 2016. http://www.cancer.org/cancer/cancercauses/othercarcinogens/intheworkplace/formaldehyde

64 Nichols, Dean. "Antimicrobial Additives in Plastics and the European Biocidal Products Directive." Plastics, Additives and Compounding 4, no. 12 (December 2002): 14–17. doi:10.1016/S1464-391X(02)80161-1.

65 Levy, S. B. "Antibacterial Household Products: Cause for Concern." Emerging Infectious Diseases 7, no. 3 Suppl (2001): 512–15.

66 Chopra, Ian. "The Increasing Use of Silver-Based Products as Antimicrobial Agents: A Useful Development or a Cause for Concern?" Journal of Antimicrobial Chemotherapy 59, no. 4 (April 1, 2007): 587–90. doi:10.1093/jac/dkm006.

67 Dow Chemical Company. "Increasing Consumer Interest in Personal and Family Wellness Creates Potential Sales Growth Opportunities for Apparel, Footwear and Home Furnishings Treated with Next-Generation Antimicrobials," September 10, 2013. http://www.dow.com/microbial/news/2013/20130910a.htm

68 Kaiser Permanente. "Prohibition of Antimicrobial Chemicals in Fabrics, Furniture and Finishes," October 15, 2015. http://www.usgbc-ncc.org/storage/images/newsletter/kp_antimicrobials.pdf?mkt_tok=3RkMMJWWfF9wsRokvK%2FBZKXonjHpfsX54u0oUa%2Bg38431UFwdcjKPmjr1YAGTMp0aPyQAgobGp5I5FENTLLYX7Nwt6AFUg%3D%3D

69 Data provided to Perkins + Will by a Dallas, TX paint supplier November 14, 2016. The cost of this particular antimicrobial paint is currently $304.95 per 5 gallons versus $192.20 per 5 gallons of standard commercial latex paint.

70 Syed, Adnan K., Sudeshna Ghosh, Nancy G. Love, and Blaise R. Boles. "Triclosan Promotes Staphylococcus Aureus Nasal Colonization." mBio 5, no. 2 (May 1, 2014): e01015–13. doi:10.1128/mBio.01015-13.

71 Levy, S. B. "Antibacterial Household Products: Cause for Concern." Emerging Infectious Diseases 7, no. 3 Suppl (2001): 512–15.

72 Yazdankhah, Siamak P., Anne A. Scheie, E. Arne Høiby, Bjørn-Tore Lunestad, Even Heir, Tor Øystein Fotland, Kristine Naterstad, and Hilde Kruse. "Triclosan and Antimicrobial Resistance in Bacteria: An Overview." Microbial Drug Resistance (Larchmont, N.Y.) 12, no. 2 (2006): 83–90. doi:10.1089/mdr.2006.12.83.

73 Soumet, C., E. Fourreau, P. Legrandois, and P. Maris. "Resistance to Phenicol Compounds Following Adaptation to Quaternary Ammonium Compounds in Escherichia Coli." Veterinary Microbiology 158, no. 1–2 (July 6, 2012): 147–52. doi:10.1016/j.vetmic.2012.01.030.

74 McBain, Andrew J., Ruth G. Ledder, Louise E. Moore, Carl E. Catrenich, and Peter Gilbert. "Effects of Quaternary-Ammonium-Based Formulations on Bacterial Community Dynamics and Antimicrobial Susceptibility." Applied and Environmental Microbiology 70, no. 6 (June 1, 2004): 3449–56. doi:10.1128/AEM.70.6.3449-3456.2004.

75 Sherwin-Williams. Paint Shield TV Commercial, 2016. https://www.youtube.com/watch?v=s2Fh-MtJWWY US Environmental Protection Agency. "Sanitizer #1 Notice of Pesticide Registration," October 8, 2015. https://www3.epa.gov/pesticides/chem_search/ppls/067603-00013-20151008.pdf

76 US Department of Commerce, NIST. "NIST Manuscript Publication Search." Accessed March 29, 2016. http://www.nist.gov/manuscript-publication-search.cfm?pub_id=914979

77 Ulrike Frank. "Identity, Grouping and Characterisation of Silver Based Biocidal Active Substances Including Nano-Silver." February 2012. https://pharosproject.net/uploads/files/sources/1828/1398436109.pdf

78 Center for Food Safety. "What Is Sewage Sludge?" Accessed August 3, 2016. http://www.centerforfoodsafety.org/issues/1050/sewage-sludge/what-is-sewage-sludge

79 Linde, Nancy. "Chemical Hazard Assessment for Nanosilver, Metallic (CAS# 7440-22-4) [Modified from GreenScreen Version 1.2]." NSF International, October 31, 2015. https://pharosproject.net/uploads/files/gs/67ee53dd37dd3b0691b37ee19797acae5622d4ba.pdf

80 Swedish Chemicals Agency. "Antibacterial Substances Leaking out with Washing Water - Analysis of Silver, Triclosan and Triclocarban in Textiles before and after Washing." Swedish Chemicals Agency, December 12, 2011. https://www.kemi.se/global/pm/2012/pm-1-12-antibact-en.pdf

81 Halden, Rolf. "On the Need and Speed of Regulating Triclosan and Triclocarban in the United States." Environmental Science & Technology 48 (March 3, 2014): 3603–11.

82 U.S. Geological Survey. "Pharmaceuticals, Hormones, and Other Organic Wastewater Contaminants in US Streams." US Geological Survey, June 2002. http://toxics.usgs.gov/pubs/FS-027-02/pdf/FS-027-02.pdf

83 Halden, Rolf. "On the Need and Speed of Regulating Triclosan and Triclocarban in the United States." Environmental Science & Technology 48 (March 3, 2014): 3603–11.

84 Oregon Department of Environmental Quality, Priority Persistent Pollutant (P3) List, http://www.deq.state.or.us/wq/SB737/docs/LegRpAtt20100601.pdf European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database The International Chemical Secretariat, SIN (Substitute It Now) List, http://sinlist.chemsec.org/

85 Drury, Bradley, John Scott, Emma J. Rosi-Marshall, and John J. Kelly. "Triclosan Exposure Increases Triclosan Resistance and Influences Taxonomic Composition of Benthic Bacterial Communities." Environmental Science & Technology 47, no. 15 (August 6, 2013): 8923–30. doi:10.1021/es401919k.

86 Centers for Disease Control and Prevention. "HAI Data and Statistics," March 2, 2016. http://www.cdc.gov/HAI/surveillance/

87 Doherty, Diane, and Edward Dunn. "Healthcare-Associated Infections: A Deeper Look." ACE Insured, October 2015. http://www.acegroup.com/us-en/news-room/wp-healthcare-associated-infections-a-deeper-look.aspx

88 Centers for Disease Control and Prevention. "HAI Data and Statistics," March 2, 2016. http://www.cdc.gov/HAI/surveillance/

89 Scott, R. Douglas. "The Direct Medical Costs of Healthcare-Associated Infections in the US Hospitals and the Benefits of Prevention." Centers for Disease Control and Prevention, March 2009. http://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf

90 Conway, Patrick. "Statement by Patrick Conway, M.D., Chief Medical Officer and Director, Office of Clinical Standards and Quality, Centers for Medicare & Medicaid Services, US Department of Health and Human Services on U.S. Efforts To Reduce Healthcare-Associated Infections," September 24, 2013. http://www.hhs.gov/asl/testify/2013/09/t20130924.html

91 Conway, Patrick. “Statement by Patrick Conway, M.D., Chief Medical Officer and Director, Office of Clinical Standards and Quality, Centers for Medicare & Medicaid Services, US Department of Health and Human Services on U.S. Efforts To Reduce Healthcare-Associated Infections,” September 24, 2013. http://www.hhs.gov/asl/testify/2013/09/t20130924.html

92 Doherty, Diane, and Edward Dunn. “Healthcare-Associated Infections: A Deeper Look.” ACE Insured, October 2015. http://www.acegroup.com/us-en/news-room/wp-healthcare-associated-infections-a-deeper-look.aspx

93 Doherty, Diane, and Edward Dunn. “Healthcare-Associated Infections: A Deeper Look.” ACE Insured, October 2015. http://www.acegroup.com/us-en/news-room/wp-healthcare-associated-infections-a-deeper-look.aspx

94 Punke, Heather. “Could a New Fabric Be the Answer to the HAI Fight?” Becker’s Infection Control & Clinical Quality, July 31, 2014. http://www.beckershospitalreview.com/quality/could-a-new-fabric-be-the-answer-to-the-hai-fight.html

95 Bearman, Gonzalo, Adriana Rosato, Kara Elam, Kakotan Sanogo, Michael Stevens, Curtis Sessler, and Richard Wenzel. “A Crossover Trial of Antimicrobial Scrubs to Reduce Methicillin-Resistant Staphylococcus Aureus Burden on Healthcare Worker Apparel.” Infection Control and Hospital Epidemiology, 2012. http://vestagen.com/wp-content/uploads/2013/04/ICHE-Bearman-March-2012.pdf

96 U.S. Department of Health and Human Services Centers for Disease Control and Prevention (CDC). “Guidelines for Environmental Infection Control in Health-Care Facilities.” Centers for Disease Control and Prevention, 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_HCF_03.pdf

97 Burns, Joseph. “Hospital-Acquired Infections.” Managed Care, February 17, 2014. http://www.managedcaremag.com/archives/2014/2/hospital-acquired-infections

98 Kaiser Permanente. “Infection Prevention and Control Plus Measures Toolkit.” Accessed August 3, 2016. http://kpnursing.org/quality/infectioncontrol/index.html

99 Schettler, Ted. “Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections?” Health Care Without Harm. Accessed March 30, 2016. https://noharm-uscanada.org/sites/default/files/documents-files/3854/Antimicrobials%20Report%202016_0.pdf

100 Healthier Hospitals Initiative. “List of Furniture and Materials That Meet the HH Healthy Interiors Goal,” January 25, 2016. http://www.healthierhospitals.org/hhi-challenges/safer-chemicals/list-furniture-and-materials-meet-hh-healthy-interiors-goal

101 Healthy Building Network. “Browse Common Products.” Pharos Project. Accessed October 6, 2016. https://pharosproject.net/material/product

Appendix A
Health & Environmental Hazards Associated with an Abbreviated List of Antimicrobial Additives Found in Building Products (alphabetical)

Abbreviation, Antimicrobial, CAS No.	Hazard Summary	Used In
BBIT (2-Butyl-1,2-benzisothiazolin-3-one) CAS: 4299-07-4	Skin Irritation, Aquatic Toxicant[1]	Sealants, Adhesives, Caulks, Wallboard, Ceiling Tiles[2]
BIT (1,2-Benzisothiazolin-3-one) CAS: 2634-33-5	Eye Irritation, Skin Sensitization, Aquatic Toxicant[3]	Paints, Adhesive[4]
Boric Acid CAS: 12179-04-3	Developmental Toxicant, Reproductive Toxicant[5]	Wood Products[6]
Copper **CAS**: 7440-50-8	Skin Sensitizer, Organ Toxicant[7] For copper dust: hazards for copper above, plus Gene Mutation, Developmental Toxicant, Mammalian Toxicant, Aquatic Toxicant[8]	Knobs/Handles, Touchable Surfaces, Ceiling Tiles, Adhesives, Textiles, Plastic articles[9]
CMIT or CIT (Methylchloroisothiazolinone) CAS: 26172-55-4	Mammalian Toxicant, Eye Irritation, Skin Irritation and Sensitization, Aquatic Toxicant[10]	Paints/Stains, Adhesives, Caulks, Grout, Wood Products[11]
CTAC (1-(3-chloroallyl)-3,5,7-triaza-1-azoniaadamantane chloride) CAS: 4080-31-3	Developmental Toxicant, Skin Sensitization[12]	Adhesives, Caulks, Grouts, Concrete Admixes, Paints[13]
DCOIT (4,5-dichloro-2-octyl-2H-isothiazol-3-one) CAS: 64359-81-5	Mammalian Toxicant, Eye and Skin Irritation, Aquatic Toxicant[14]	Caulks, Sealants, Grouts[15]
DDAC (Alkyl didecyl dimethyl ammonium chloride) CAS: 7173-51-5	Respiratory Sensitizer, Eye and Skin Irritation, Aquatic Toxicant[16]	Wood Products[17]
Elemental Silver / Silver Nanoparticles CAS: 7440-22-4	Mammalian Toxicant, Skin sensitization, Aquatic Toxicant[18] For silver nanoparticles: Hazards for silver above, plus Endocrine Disrupter, Organ Toxicant[19]	Upholstery & Fabrics, Hardware, Touchable Surfaces, Tile Installation Products, Ceramic Tile, Countertops, Adhesives, Sealants, Paints, Carpets, Textiles[20]
Formaldehyde CAS: 50-00-0	Carcinogen, Developmental Toxicant, Mutagen, Respiratory Sensitizer, Mammalian Toxicant, Eye Irritation, Skin Irritation, Skin Sensitization[21]	Released into wet-applied products by certain preservative additives[22]
IPBC (3-iodo-2-propynyl butylcarbamate) CAS: 55406-53-6	Developmental Toxicant, Eye Irritation, Skin Sensitization, Organ Toxicant, Aquatic Toxicant[23]	Paints/Stains, Wire & Cable, Carpets, Textiles, Wood Product[24]
MIT (Methylisothiazolinone) CAS: 2682-20-4	Mammalian Toxicant, Skin Irritation and Sensitization, Aquatic Toxicant[25]	Paints/Stains, Adhesives, Caulks, Grout, Wood Products[26]
OBPA (Oxybisphenooxyarsine) CAS: 58-36-6	PBT, Carcinogen, Developmental Toxicant, Neurotoxicant, Mammalian Toxicant, Organ Toxicant, Aquatic Toxicant[27]	Flexible PVC, Adhesives, Coatings, Textiles[28]
OIT (2-n-octyl-4-isothiazolin-3-one) CAS: 26530-20-1	Developmental Toxicant, Mutagen, Mammalian Toxicant, Eye and Skin Irritation, Skin Sensitizer, Aquatic Toxicant[29]	Adhesives, Textiles, Wood Products[30]
Propiconazole CAS: 60207-90-1	Endocrine Disruptor, Aquatic Toxicant[31]	Wood Products, Paints, Coatings, Caulks, Adhesives[32]
QACs (Quaternary Ammonia Compounds) CAS: specific to individual substances	Respiratory Sensitizer, Asthmagen[33]	Disinfection Products, Wood Products, Specialty Paints[34]
Silver Zeolite CAS: 130328-18-6	At the time of publishing, no authoritative source used in the Pharos Chemical and Material Library associates this substance with health hazards.	Paints, Carpet Fibers, Wallpaper, Adhesives, Fabrics/Textiles[35]
Triclosan (2,4,4'-trichloro-2'- hydroxy-diphenyl-ether) CAS: 3380-34-5	PBT, Endocrine Disruptor, Aquatic Toxicant[36]	Textiles, Plastic Sheets/Parts, Adhesives, Caulk, Coatings, Tile Installation Products, Hardware, Ceramic Tile, Carpets, Countertops[37]
ZPT (Zinc pyrithione) CAS: 13463-41-7	Reproductive Toxicant, Mammalian Toxicant, Eye Irritant, Skin Sensitization, Aquatic Toxicant[38]	Fabrics/Textiles, Wall Coverings, Adhesives, Caulks, Sealants, Grouts, Joint Compounds[39]

Sources for Appendix A

1 European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

2 "Vanquish 100 Antimicrobial Label," February 8, 2016. https://www3.epa.gov/pesticides/chem_search/ppls/001258-01249-20160208.pdf

3 European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm

4 "Canguard BIT 20 AS Preservative - Notice of Pesticide Reregistration," December 29, 2010. https://www3.epa.gov/pesticides/chem_search/ppls/000464-00719-20101229.pdf Dow. "Canguard BIT 20 DPG Preservative Product Information," April 30, 2005. http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_005b/0901b8038005b792.pdf?filepath=biocides/pdfs/noreg/253-01717.pdf&fromPage=GetDoc

5 European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

6 "Borax 5 Mol," November 18, 2011. https://www3.epa.gov/pesticides/chem_search/ppls/001624-00001-20111118.pdf

7 Government of Japan, GHS Classifications http://www.nite.go.jp/en/chem/ chrip/chrip_search/intSrhSpcLst?_e_trans=&slScNm=CI_01_001&bcPtn=6

8 Dust hazards may be relevant during manufacture, installation, demolition, and during activities such as sawing, sanding, grinding, and intensive cleaning, and if the product otherwise degrades during use. The hazard is not otherwise expected to be present during normal use. New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx; MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm

9 "Antimicrobial Copper Alloys - Group I and Associated Fabricated Products Master Label," August 26, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/082012-00001-20140826.pdf Fuji Chemical Industries. "Bactekiller AC," September 29, 2004. https://www3.epa.gov/pesticides/chem_search/ppls/059824-00001-20040929.pdf

10 Republic of Korea, GHS Classification and Labelling for Toxic Chemicals, http://ncis.nier.go.kr/ghs/hcs/en/search/search_en_01.jsp New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx

11 "Kathon 7G Antimicrobial - Notice of Pesticide Registration," April 29, 2015. https://www3.epa.gov/pesticides/chem_search/ppls/000464-08135-20150429.pdf

12 MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm

13 "Dowicil 75 Preservative Master Label," March 8, 2016. https://www3.epa.gov/pesticides/chem_search/ppls/000464-00403-20160308.pdf

14 New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx

15 "Bioban DC 9P5 Antimicrobial Notice of Pesticide Registration," February 24, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/000464-00786-20140224.pdf

16 Association of Occupational and Environmental Clinics Exposure Code List, http://www.aoec.org/tools.htm

17 "Secure Label," March 6, 2009. https://www3.epa.gov/pesticides/chem_search/ppls/001022-00592-20090306.pdf

18 Government of Japan, GHS Classifications, http://www.nite.go.jp/en/chem/chrip/chrip_search/intSrhSpcLst?_e_trans=&slScNm=CI_01_001&bcPtn=6; New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx

19 Government of Japan, GHS Classifications, http://www.nite.go.jp/en/chem/chrip/chrip_search/intSrhSpcLst?_e_trans=&slScNm=CI_01_001&bcPtn=6 New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx; The Endocrine Disruptor Exchange (TEDX) http://www.endocrinedisruption.org/popup-chemical-details?chemid=810 Linde, Nancy. "Chemical Hazard Assessment for Nanosilver, Metallic (CAS# 7440-22-4) [Modified from GreenScreen Version 1.2]." NSF International, October 31, 2015. https://pharosproject.net/uploads/files/gs/67ee53dd37dd3b0691b37ee19797acae5622d4ba.pdf

20 "Irgaguard B 5000 Silver-Zinc Zeolite," 6.20/12. https://pharosproject.net/uploads/files/sources/1828/1397591706.pd "Silvadur AQ Antimicrobial Notice of Pesticide Registration," July 20, 2012. https://www3.epa.gov/pesticides/chem_search/ppls/000464-00783-20120720.pdf

21 International Agency for Research on Cancer (IARC), http://monographs.iarc.fr/ENG/Classification/latest_classif.php MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm Government of Japan, GHS Classifications, http://www.nite.go.jp/en/chem/chrip/chrip_search/intSrhSpcLst?_e_trans=&slScNm=CI_01_001&bcPtn=6; USEPA Extremely Hazardous Substances - EPCRA Section 302, https://www.epa.gov/sites/production/files/2015-03/documents/list_of_lists.pdf

22 See for example, "THOR Specialties, Inc – Biocides – Pioneers in the Development of Protection Technology for Biocides for Dry Film Applications." Accessed March 29, 2016. http://www.thor.com/usa/biocides.html

23 MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

24 "Filmguard IPBC 1000 Fungicidal Agent," December 22, 2009. https://www3.epa.gov/pesticides/chem_search/ppls/000464-08123-20091222.pdf

25 Republic of Korea, GHS Classification and Labelling for Toxic Chemicals, http://ncis.nier.go.kr/ghs/hcs/en/search/search_en_01.jsp MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm

26 "Kathon 7G Antimicrobial - Notice of Pesticide Registration," April 29, 2015. https://www3.epa.gov/pesticides/chem_search/ppls/000464-08135-20150429.pdf

Sources for Appendix A

27 Oregon Department of Environmental Quality, Priority Persistent Pollutant (P3) List, www.deq.state.or.us/wq/SB737; USEPA, Risk Management Actions & TSCA Work Plans. www.epa.gov/oppt/existingchemicals/ Philippe Grandjean and Phil Landrigan, "Developmental neurotoxicity of industrial chemicals, List of 201 Chemicals known to be neurotoxic in man", www.fundrogertorne.org/salud-infancia-medio-ambiente/pdf/developmental-neurotoxicity-of-industrial-chemicals-grandjean-landrigan.pdf USEPA, Extremely Hazardous Substances - EPCRA Section 302, https://www.epa.gov/sites/production/files/2015-03/documents/list_of_lists.pdf European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database

28 "Micropel 5 DIDP," January 2, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/005383-00125-20140102.pdf

29 MAK Commission of Germany List of Substances with MAK & BAT Values & Categories, http://onlinelibrary.wiley.com/book/10.1002/3527600418/homepage/access_to_the_list_of_mak_and_bat_values.htm Republic of Korea, GHS Classification and Labelling for Toxic Chemicals, http://ncis.nier.go.kr/ghs/hcs/en/search/search_en_01.jsp European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database New Zealand HSNO Chemical Classifications www.epa.govt.nz/search-databases/Pages/HSNO-CCID.aspx

30 "Mergal OIT Technical Notice of Pesticide Registration," February 18, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/000365-00086-20140218.pdf

31 The Endocrine Disruptor Exchange (TEDX) http://www.endocrinedisruption.org/endocrine-disruption/tedx-list-of-potential-endocrine-disruptors/overview European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria ec.europa.eu/enterprise/sectors/chemicals/documents/classification/

32 "Preventol A 12 Notice of Pesticide Registration," May 7, 2012. https://www3.epa.gov/pesticides/chem_search/ppls/039967-00092-20120507.pdf

33 Association of Occupational and Environmental Clinics Exposure Code List, http://www.aoec.org/tools.htm

34 NIH QACs webpage http://nems.nih.gov/soc/Pages/Quaternary-Ammonium-Compounds-(QACs-or-Quats).aspx US Environmental Protection Agency. "Sanitizer #1 Notice of Pesticide Registration," October 8, 2015. https://www3.epa.gov/pesticides/chem_search/ppls/067603-00013-20151008.pdf

35 Fuji Chemical Industries. "Bactekiller A," October 21, 2003. https://www3.epa.gov/pesticides/chem_search/ppls/059824-00003-20031218.pdf

36 Oregon Department of Environmental Quality, Priority Persistent Pollutant (P3) List, http://www.deq.state.or.us/wq/SB737/docs/LegRpAtt20100601.pdf European Union, Regulation on the Classification, Labelling and Packaging of Substances and Mixtures (CLP) Annex 6 Table 3-1 - GHS Hazard code criteria. http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database The International Chemical Secretariat, SIN (Substitute It Now) List, http://sinlist.chemsec.org/

37 "Microban Additive B Label," August 23, 2013. https://www3.epa.gov/pesticides/chem_search/ppls/042182-00001-20130823.pdf

38 Government of Japan, GHS Classifications, http://www.nite.go.jp/en/chem/chrip/chrip_search/intSrhSpcLst?_e_trans=&slScNm=CI_01_001&bcPtn=6

39 "Zinc Omadine Powder Industrial Microbiostat Label," December 19, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/001258-00840-20141219.pdf

Appendix B
Preservatives Versus Health Claims: Decoding Antimicrobial Marketing

APPENDIX B

Consumers feel a misplaced confidence in antimicrobial building products, in part, because of confusing, and in some instances, highly misleading marketing materials made possible by the extremely complex regulation governing this sector. This regulation is known by the acronym FIFRA, which stands for the Federal Insecticide, Fungicide and Rodenticide Act, and is overseen by the US Environmental Protection Agency.

There are several ways in which FIFRA makes it difficult for the average person to interpret marketing materials about a product's antimicrobial properties.

1. The EPA must use a case-by-case approach to regulating pesticides.[1]

Rather than regulate antimicrobials by substance, FIFRA requires the EPA to regulate antimicrobials based on how they are used in a product, and how that product will be marketed. For example, nanoscale silver has the same inherent hazards to humans and the environment regardless of its function in a product, or the words used on a product's packaging. But the EPA would only consider it subject to regulation if a manufacturer wanted to advertise a product incorporating it as being able to kill microbes that could make a person sick. This is known as making a health claim under FIFRA. Cautious that the public will see these claims, feel a false sense of security, and let basic sanitation habits lapse, the EPA closely monitors the language used to market these products.[2] Manufacturers must also provide documentation that the use of the product as intended will not present an unreasonable risk to the environment or food supply.[3]

If the same nanoscale silver compound was added to an identical product, and as long as the manufacturer did not seek to make a health claim, the product is exempted from further regulation. This is known as a treated article exemption under FIFRA. **The agency does not verify manufacturers' assertions about exempted products' abilities to control target organisms, nor does it evaluate them for health and environmental impacts.[4]**

2. The language considered to be a health claim is very specific.

In 2000 the EPA issued a notice attempting to clarify the distinction between products making health claims and those considered treated articles. That notice lists just seven scenarios where marketing language constitutes a health claim, and therefore subject to regulation under FIFRA:[5]

1. A claim that the product controls microorganisms that are infectious to the public.
2. Any claim that a product sterilizes, disinfects, kills viruses, or sanitizes.
3. A claim that uses the specific terms "antibacterial," "bactericidal," or "germicidal."
4. A claim that the product can be used against infectious fungi.
5. Claims that the product can control the spread of allergens because it can control the growth of mold or mildew.
6. Any claim that the product will have a benefit to public health where it is applied.
7. Claiming that a product is "antimicrobial" without qualifications.

3. The language the EPA considers to be making a health claim is also very subjective.[6]

Marketing claims falling outside these parameters are not considered to be health claims, unless they imply a health benefit. Each person may interpret marketing materials differently, making the measure of implication highly subjective.

Further, the agency's guidance assumes consumers will recognize subtle differences in terms the public tends to think of as synonymous. For example, a product marketing itself as "antibacterial" is making a health claim, while the term "antimicrobial" is considered suitable for marketing a treated article, as long as the marketing specifies elsewhere that the microbes in question aren't those that will make a person sick.

4. While they do not benefit our health, some products require antimicrobials for preservation.

The treated article exemption is intended for preservatives because in these instances, anti-microbials only protect the product from spoilage, degradation or damage caused by microorganisms. These microbes can use a wide variety of substances as food,[7] and only require water to begin to grow and multiply, often negatively impacting the aesthetic and/or performance characteristics of a product.[8] Because of their water content, wet-applied products (paints, coatings, etc.) are inherently vulnerable to microbes. As a result, water-based paints, adhesives, and other wet-applied products typically contain preservatives to prevent microbial activity during the product's storage,[9] or to protect the surface of the paint, caulk, etc., once it has been applied and has dried.[10]

Preservatives can also be required in solid materials. For example, additives compounded into plastics can act as a food source to microbes, and make it more vulnerable to degradation. As microbes digest these additives, the plastic can become discolored or brittle.[11] In 2002, an industry expert reported that the flexible polyvinyl chloride (PVC) industry consumed most of the antimicrobial additives used in plastics in the US. These vinyl products are vulnerable to microbes that digest the plasticizers that make these products flexible.[12] Polyurethanes and polyesters are also especially vulnerable to microbes.[13] The shape of a plastic article is another factor its ability to resist microbes, as items with more surface area will degrade more quickly.[14]

Manufacturers also treat bio-based materials with antimicrobial additives. For example, fungi present in freshly sawn logs can create a blue stain on planks milled from the wood, called sapstain. Sawmills routinely dip or spray fresh lumber in a solution of anti-sapstain treatments to prevent this, and to prevent future rot from secondary fungal growth.[15] Further, the addition of bio-based materials to polymers (vegetable oils in plastics, wood dust in composite decking, etc.) increases vulnerability to microbial action, and these products may require higher levels of preservatives than would have been necessary otherwise.[16]

FIFRA provides an opportunity for manufacturers to mislead consumers about the benefits of antimicrobial products, whether they intend to do so or not.

The term "registration" can be interpreted by consumers to be an indication of the EPA's seal of approval.

All substances that can be used as pesticides need to be registered with the EPA. The agency then gives the substance a unique registration number, and adds it to a database. (The EPA estimates that 275 substances are registered with the Agency as pesticides.)[17] Advertising can include statements that a building product contains an EPA registered antimicrobial and is resistant to X, Y, or Z. While a consumer may interpret this to mean that the EPA has reviewed the antimicrobial in question and has issued a registration as an indication that it is effective, beneficial, or even harmless, the reality is that the EPA registration simply indicates that the antimicrobial additive is considered a pesticide by the agency.

Remember that in the case of treated articles, the EPA does not verify manufacturer claims of efficacy against microbes, or evaluate its health or environmental impacts.[18]

Antimicrobial ingredients may be added to building products as preservatives even though the products do not require preservation—as a marketing ploy.

For example, "looking for a way to innovate and differentiate from their competition," a countertop company incorporated an antimicrobial into an engineered stone product. Despite the fact that this additive is a preservative—and has no benefit to human health—the company saw a 38% rise in annual revenue, and a 48% increase in market share.[19] Since the antimicrobial was added to the product in an effort to "innovate" and "differentiate," and research finds that engineered stone countertops do not uniformly require a preservative,[20] it is difficult to believe that this antimicrobial was a necessary additive.

In another example, door hardware coated with antimicrobials are available. The antimicrobial is a preservative only, and is added to protect the hardware from mold, mildew, and odor-causing bacteria.[21] How endemic is the problem of moldy door knobs that this coating is necessary? The manufacturer of the hardware advises that they be cleaned just as frequently as standard hardware would be,[22] so it is unclear what advantage this antimicrobial additive provides in practice.

A third example of this phenomenon is of light switches and covers that are coated with an antimicrobial additive.[23] Product literature highlights independent laboratory testing showing the additive is effective against bacteria such as MRSA (a drug-resistant strain of staphylococcus), while only briefly confirming elsewhere, in smaller text, that the antimicrobial additive is present only as a preservative that protects the switch and cover from mold, mildew, and other microbes that may jeopardize the "integrity of the product."[24] This disclaimer confirms that despite listing infectious MRSA as a microbe targeted by the antimicrobial additive, the additive is a preservative only, and is not formally making a health claim under FIFRA.

The EPA is concerned about the growing use of a wide variety of antimicrobial claims made in marketing materials. The agency takes "very seriously" public health claims it finds to be unsubstantiated.[25] At the time of publication, a search of the EPA's database of Administrative Enforcement Dockets related to FIFRA infractions returned 1,000 case numbers, dating back to 2000.[26]

In a 1998 bulletin, the agency warned:

> *EPA is concerned about these statements because, in addition to being unlawful, they are also potentially harmful to the public—if people believe that the product has a self-sanitizing quality, they may not practice standard hygiene to prevent the transmission of harmful germs. Consequently public health may be less protected. For that reason, EPA advises consumers not to rely on antibacterial claims as a substitute for following common-sense hygienic practices. EPA does not know whether these treated products work as claimed.*[27]

Sources for Appendix B

1 The ACTA Group, L.L.C. "Recent Regulatory Developments." Accessed April 12, 2016. http://www.actagroup.com/regulatory-developments/update/monthly-update-april-2015

2 US Environmental Protection Agency, OARM. "Consumer Products Treated with Pesticides," April 1998 (1).

3 US Environmental Protection Agency, OA. "Summary of the Federal Insecticide, Fungicide, and Rodenticide Act." Overviews and Factsheets. Accessed March 29, 2016. https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act

4 Schettler, Ted. "Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections?" Health Care Without Harm. Accessed March 30, 2016 (16). https://noharm-uscanada.org/sites/default/files/documents-files/3854/Antimicrobials%20Report%202016_0.pdf

5 US Environmental Protection Agency. "Pesticide Registration Notice 2000." US EPA, March 6, 2000.

6 US Environmental Protection Agency. "Pesticide Registration Notice 2000." US EPA, March 6, 2000.

7 Gerritsen, Lonne. "Evaluation Manual for the Authorisation of Plant Protection Products and Biocides." Board for the Authorisation of plant protection products and biocides, January 2013. http://ctgb.nl/docs/default-source/toetsingskader-biociden/Evaluation-Manual-biocides-EU-part/b_7_efficacy_pt6_in_can_preservatives_eu_em_1-.pdf?sfvrsn=2

8 Nichols, Dean. "Antimicrobial Additives in Plastics and the European Biocidal Products Directive." Plastics, Additives and Compounding 4, no. 12 (December 2002): 14–17. doi:10.1016/S1464-391X(02)80161-1.

9 Gerritsen, Lonne. "Evaluation Manual for the Authorisation of Plant Protection Products and Biocides." Board for the Authorisation of plant protection products and biocides, January 2013. http://ctgb.nl/docs/default-source/toetsingskader-biociden/Evaluation-Manual-biocides-EU-part/b_7_efficacy_pt6_in_can_preservatives_eu_em_1-.pdf?sfvrsn=2

10 European Commission. "What Are Biocides and How Widely Are They Used?" Accessed March 28, 2016. http://ec.europa.eu/health/opinions/en/biocides-antibiotic-resistance/l-3/1-definition-antimicrobials.htm

11 Chalmers, John M., and Robert J. Meier. Molecular Characterization and Analysis of Polymers. Elsevier, 2008.

12 Markarian, Jennifer. "Antimicrobial Plastics Additives: Trends and Latest Developments in North America." Plastics, Additives and Compounding 4, no. 12 (December 2002): 18–21. doi:10.1016/S1464-391X(02)80162-3.

13 Gadd, Geoffrey Michael. Fungi in Biogeochemical Cycles. Cambridge University Press, 2006.

14 Chalmers, John M., and Robert J. Meier. Molecular Characterization and Analysis of Polymers. Elsevier, 2008.

15 Szenasy, Erika. "Assessing the Potential Impact of the Antisapstain Chemicals, DDAC and IPBC, in the Fraser River." Environment Canada, April 1, 1999. https://pharosproject.net/uploads/files/sources/1828/1329771116.pdf

16 Markarian, Jennifer. "Rethinking Biocides for Plastics." Compounding World, July 2013.

17 US Environmental Protection Agency, OCSPP. "What Are Antimicrobial Pesticides?" Overviews and Factsheets. Accessed March 28, 2016. https://www.epa.gov/pesticide-registration/what-are-antimicrobial-pesticides

18 Schettler, Ted. "Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections?" Health Care Without Harm. Accessed March 30, 2016 (16). https://noharm-uscanada.org/sites/default/files/documents-files/3854/Antimicrobials%20Report%202016_0.pdf

19 Microban International. "Silestone Case Study." Accessed March 29, 2016. http://www.microban.com/about-microban/case-studies/silestone-case-study.

20 Healthy Building Network. "Common Product: Engineered Stone." Pharos Project, 2016. https://pharosproject.net/material/show/2078889

21 See for example, "US Environmental Protection Agency. "Agion Silver Antimicrobial Type AL Label," October 7, 2014. https://www3.epa.gov/pesticides/chem_search/ppls/088165-00002-20141007.pdf

22 SARGENT Manufacturing Company,. "A Whole New Kind of Building Security." Accessed March 29, 2016. http://www.sargentlock.com/solutions/microshield/

23 See for example, "Leviton Manufacturing Co. "Antimicrobial Treated Devices." Accessed March 28, 2016. http://www.leviton.com/OA_HTML/SectionDisplay.jsp?section=66321&minisite=10251

24 Leviton Manufacturing Co., Inc. "Antimicrobial Treated Devices from Leviton," 2014. http://www.leviton.com/OA_HTML/ibcGetAttachment.jsp?cItemId=9SsCO-7Ck1nFi0WOCbfU3g&label=IBE&appName=IBE&LEVCOMP_pses=ZG823CD6CD65D6C2489460ED2083C88A81F1F11FDF76242E07E35629C19E119CA10E6C19D24487FA4B8DBC089655CC8D5199BE0165DAD1F3D8&minisite=10251

25 US Environmental Protection Agency. "Press Release: 'The North Face' Parent Company, 'Saniguard' Marketers, and Califone Fined More Than $500,000 Over Antimicrobial Claims." Accessed March 29, 2016. https://yosemite.epa.gov/opa/admpress.nsf/0/AC0C1AF1625888608525771B00561E83

26 US Environmental Protection Agency. "EPA Administrative Enforcement Dockets - FIFRA." Accessed March 25, 2016. https://yosemite.epa.gov/OA/RHC/EPAAdmin.nsf/Advanced%20Search?SearchView&Query=fifra&SearchMax=0

27 US Environmental Protection Agency, OARM. "Consumer Products Treated with Pesticides," April 1998.