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Solving the Hospital Acquired Infection Crisis and Microbial Cross-Contamination Problems in in Health Care and Related Applications

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Introduction

A new class of anti-microbials promises to be an effective tool in the growing global threat from hospital-acquired infections and microbial cross contamination.

Hospital acquired infections (HAI) are a global crisis.
In the USA alone, estimates of expenses related to HAI exceed $30 billion and over 200,000 cases. 5-10% of all admissions, or approximately 2 million acquire *HAI resulting in nearly 100,000 deaths,* $15K non-reimbursable cost per patient, over 2.6 MM additional bed days and an additional $35-40,000 in increased per patient costs.
In Europe there are 25,000 deaths each year caused by HAI.
These numbers are even higher on a percentage basis globally.

The most common HAI is Methicillin-resistant staphylococcus aureus (MRSA) that is prevalent and increasing in incidence outside of hospitals, especially in school and athletics with several high profile sports figures being side-lined with MRSA infections.

A potentially larger threat has arisen from a category of bacteria that are already killing tens of thousands of hospital patients each year. These are known as "Gram-negative " bacteria (named for the way they react to a chemical indicator used to classify bacteria).

Many drugs that are approved for treating MRSA are ineffective Gram-negative bacteria and germs are evolving and continuing to be more immune and more resistant to existing treatments.

Dr. Louis B. Rice, an infectious-disease specialist at the Louis Stokes Cleveland V.A. Medical Center and Case Western Reserve University says "In many respects it's far worse than MRSA. There are strains out there, and they are becoming more and more common, that are resistant to virtually every antibiotic we have."

These Gram-negative bacteria can cause severe pneumonia, urinary tract infections, and

infections bloodstream and other parts of the body.

Examples of Gram-negative bacteria include Acinetobacter, Citrobacter, Enterobacter, Enterococcus, Escherichia coli, Klebsiella, Legionella, Proteus, Pseudomonas, and Salmonella.

According to State University of New York Researchers, more than 20 percent of the Klebsiella infections are now resistant to virtually all modern antibiotics.

Gram-negative bacteria have cell structures that help make them more resistant to anti-biotics and disinfectants and as a result they are present in large numbers on hospital surfaces where they infect though entry points to the body such as injections, catheters, wounds and respirators.

Contamination vectors include cell phones, pagers, stethoscopes, scrubs, curtains and other hospital textiles, handrails, door handles, wheelchair and armrests, catheters and airborne sources.

Problem

HAI's are caused by bacterial migration throughout the hospital as a result of direct or indirect contact vectors. Current hygiene and disinfection protocols use disinfectants to kill microbes, or require single-use medical supplies. Disinfectants kill but do not prevent re-growth or cross-contamination after a certain time.
Hand washing mitigates direct transfer but not indirect transfer.

Previous Options

Disinfectants and sanitizers fall into two broad categories: leaching, and non-leaching.
Leaching anti-microbials kill by poisoning microbes and spread into the environment to provide a "zone-of-inhibition" commonly seen on tests on laboratory Petri dishes. This allows disinfection beyond the area of contact. By definition these materials lose their efficacy as they migrate and are either consumed or reduced in concentration as they spread out.
More importantly, the killing mechanism is a poisoning action that typically interrupts cellular function by inhibiting cell-transport mechanisms, cell-reproductive functions. With the very large populations of microbes that exist everywhere, a small proportion of these can exhibit genetic differences that render them less susceptible to this poisoning mechanism. These slightly-resistant specimens are responsible for subsequent generations of increasing resistance to these disinfectants, the so-called "super bugs". In the unfortunate event of a specimen being very resistant or immune to the poisoning, an entire population of resistant microbes results. This mechanism is called mutagenicity and occurs when the killing chemical is a leaching anti-microbial and has resulted in species such as many strains of staphylococcus aureus, enterococci, pneumococci, staphylococci, tuberculosis, klebsiella, and pseudomonas aeruginosa being currently resistant to most or all antimicrobials that were once effective. Methicillin-resistant staphylococcus aureus (MRSA), and vancomycin resistant enterococci (VRE) are among the most common and deadly of these threats. In the USA, more people died of MRSA infections than of AIDS.

Common leaching disinfectants include alcohols, aldehydes, bleach, ethylene oxide, ozone, peroxides, phenols, quats, silver and heavy metal compounds, and triclosan. In addition to their diminishing efficacy over time, many of these contain solvents or are corrosive. Some have been linked to carcinogenic results.

Non-leaching anti-microbials kill by physically destroying microbes. This prevents mutagenicity – that is it does not allow the formation of resistant strains. While they do not create a zone-of-inhibition because they do not migrate, they remain attached to a surface and protect that surface from microbial attack and cross-contamination.

Examples of non-leaching anti-microbials include silane-quats, certain bound silver and copper compounds. Some of these may contain solvents or have limited efficacy against the broad spectrum of microbes, be corrosive or affect colour and feel of a substrate.

A helpful analogy is that the microbe can build immunity to poisoning (leaching) but it cannot build immunity to having its "head" cut off (non-leaching).

An Ideal Solution

An ideal anti-microbial would provide the following benefits:

Effectiveness

The ideal solution would deliver broad-spectrum efficacy against bacteria, viruses, moulds, fungi and protozoa.

Safety

The ideal solution would be non-toxic and safe.

Durability

The ideal solution would be durable and continue to act effectively for several days to weeks – it would protect contamination vectors between cleaning regimens and would be durable enough to resist removal by these regimens be they disinfection, sanitization or laundering.

Non-mutagenicity

The ideal solution would not create super-bugs by using a physical killing mechanism and thus removing the poisoning cycle that leads to resistance.

Eco-responsibility

The ideal solution would be water-based, have no adverse volatile organic emissions and have no adverse environmental impact during its entire life cycle.

Cost-Effectiveness

The ideal solution would be competitive in cost and be a significant improvement over current offerings in effective cost when potential for recontamination or cross-contamination are factored.

Currently, non-leaching anti-microbials represent the best available solution.
Within these, certain silver and copper-based chemicals have shown limited anti-viral activity, discolouration and have been expensive. Nano-silver has not been evaluated for long-term health and environmental issues.

Silane-quats, a technology invented by Dow Chemicals about 40 yeas ago have proven efficacy, non-mutagenicity and durability.
Original versions of these were limited in their applicability and safety because of solvent content. This restricted use in mainstream cleaning and protecting regimens.
Over the last three years, innovations in process chemistry have allowed silane quats to be diluted into stable water-based formulations. This has allowed all of the efficacy, non-mutagenicity and durability benefits of the original chemistry with safety and eco-responsibility now available. This has allowed the new silane-quats to be applied as fabric treatments, protecting solutions and surface treatments for contaminations discussed earlier such as cell phones, scrubs, stethoscopes etc.

Implementation

Silane quats can be seamlessly integrated into the HAI and cross-contamination reduction protocol in the following ways:

- Disinfection using non-mutagenic and water-based chemicals with shortest kill times
- Surface protection following (this) disinfecting regimen by spraying or wiping down the surface with a water-based silane quat solution. This includes unobvious hotspots such as elevator buttons, handrails, countertops, medical test equipment, cell phones, pagers, etc.
- Spraying all surfaces such as walls and ceilings to allow silane-quat treatment to scrub the air
- Specifying material treatment of textiles in hospitals including scrubs, sheets, curtains, towels, mattress covers, gowns, etc.
- Replenishing treatments on a regular schedule
- Specifying silane-quat treatment, where possible, at the OEM level in key contamination vectors such as stethoscopes, medical device housings, textiles etc.

Summary

Silane-quats represent a significant step, and possibly the only current single-source solution to the growing global problem of hospital-acquired infections and the cross-contamination that spreads this global problem within health-care facilities as well as out into the public sector.

Recent advances in process technology have allowed a **safe, effective, water-based**, silane-quat solution be made available to hospitals, OEM manufacturers and janitorial and sanitation providers. Manufacturers, customers and consumers have the ability to benefit while ensuring that **eco-responsibility** is not compromised.
The proven ability of silane-quats to destroy a wide range of commonly encountered microbial threats without **mutagenicity** is the **necessary** component in preventing cross transmission of microbes and preventing outbreaks of hospital acquired infections.

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References

1. Effectiveness of Silane-quats

The following table lists the pathogens that are killed or inactivated following application of Si-QUAT to various substrates and materials. This table does not reflect the activity of Si-QUAT in the liquid form.

PATHOGENS INACTIVATED BY SIQUAT APPLICATION

Gram Positive Bacteria	**Reference**
Bacillus sp. (vegetative cell)	5, 6, 11
Corynebacteriumdiptheriae	1, 13
Micrococcus lutea	5, 6, 11
Micrococcus sp.	2, 5, 15
Mycobacterium tuberculosis	14
Mycobacterium smegmatis	14
Propionibacterium acnes	5
Staphylococcus aureus *	2, 3, 5, 6, 10, 11, 13, 24, 15, 21
Staphylococcus epidermidis	2, 5, 6, 7, 11, 13, 14, 15
Streptococcus faecalis	2, 5, 6, 7, 11, 13, 14
Streptococcus mutans	5, 6, 7, 11
Streptococcus pneumonia	1
Streptococcus pyrogenes	5, 6, 7, 11
Gram Negative Bacteria	
Acinetobacter calcoaceticus	2, 5, 6, 11, 14, 15
Aeromonas hydrophilia	5, 6, 11
Citrobacter deversus	5, 6, 11
Citrobacter freundi	5, 6, 11
Enterobacter aerogenes	5, 6, 7, 11
Enterobacter aglomerans	2, 5, 14, 15
Enterobacter cloacae	5, 6, 7, 11
Enterococcus	10
Escherichia coli	1, 2, 3, 5, 6, 7, 10, 11, 13,
Klebsiella oxytoca	5, 6, 11, 14
Klebsiella pneumoniae	3, 5, 6, 7, 9 10,11,13,14
Klebsiella terriena	19
Legionella pneumophila	1
Morganella morganii	5, 6, 7, 11
Proteus mirabilis	5, 6, 7, 11
Proteus vulgaris	5, 6, 7, 11
Pseudomonas aeruginosa	2, 3, 5, 6, 7, 11, 13, 14
Pseudomonas fluorscens	5, 6, 7, 10, 11
Salmonella cholera suis	5, 6, 7, 11, 14
Salmonella typhi	5, 6, 7, 11, 14
Salmonella typhimurium	1, 5, 6, 7, 11
Serratia liquifaciens	5, 6, 7, 11
Serratia marcescens	5, 6, 7, 11
Xanthomonas campestris	5, 6, 7, 11
Viruses	
Adenovirus Type II & IV	17, 18, 21
Bovine Adenovirus Type I & IV	17, 18, 21
Feline pneumonitis	21
Herpes Simplex Type I	16, 17, 18
Herpes Simplex Type II	21
HIV-1 (AIDS)	21
Influenza A2 (Aichi)	17, 18, 21
Influenza A2 (Asian)	17, 18
Influenza B	17, 18
Mumps	17, 18
Parinfluenza (Sendai)	21
Rous Sarcoma	17, 18
Reovirus Type I	17, 18
Simian Virus 40	17, 18
Vaccinia	17, 18
MS2	19
PRD1	19
Fungi, Algae, Mould, Yeast, Spores	
Alterania alternate	8,12
Aphanizomenon sp.	22
Aspergillus flavus	2, 5, 6, 7, 11, 14
Aspergillus niger	2, 5, 6, 7, 8, 11, 12, 13, 14
Aspergillus sydowi	5, 6, 7, 11
Aspergillus terreus	5, 6, 7, 11, 14
Aspergillus versicolor	2, 5, 6, 7, 11
Aspergillus verrucaria	14
Aureobasidium pullans	5, 6, 7, 8, 11, 12
Candida albicans	1, 2, 5, 6, 7, 14
Candida pseudotropocalis	5, 6, 7, 11
Chaetomium globsum	1
Cladosporium cladosporioides	8, 12
Chlorella vulgaris	19
Dreschslera australiensis	8, 12
Epidermophyton sp.	9
Gliomastix cerealis	8, 12
Gloeophyllum trabeum	5, 6, 7, 11
Microsporum sp.	9
Microsporu maudouinii	21
Monilia grisea	8, 12
Oscillatoria	20
Penicillium chrysogenum	5, 6, 7, 11
Penicillium commune	8, 12
Penicillium funiculosum 14	1, 2, 5, 6, 7, 11,
Penicillium pinophilium	5, 6, 7, 11
Penicillium variable	5, 6, 7, 11, 14
Phomafimeti	8, 12
Pithomyces chartarum	8, 12
Poria placenta	5, 6, 7, 11
Scenedesmus	20
Saccharomyces cerevisiae	5, 6, 7, 11, 13, 14
Scolecobasidium humicola	8, 12
Selenastrum sp.	22
Trichoderma viride	5, 6, 7, 11
Trichophyton interdigitale	2, 14
Trichophyton maidson	14
Trichophyton mentogrophytes	5, 6, 7, 9, 11
Trichophyton sp.	9
Protozoa Parasites	
Cryptosporidium parvum (oocysts)	19

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2. Effectiveness of Silane-quats in a Hospital Test

"Fungal remediation and protective antimicrobial treatment of a ten storey grossly contaminated hospital"
S. Kumar, Satish Bakhda and WC White reported the following:

After over five years of planning and construction, two months old newly open Hospital Sultan Ismail was infested with deadly fungus. The areas of the extensive visible mold growth (Aspergillus fumigatus) were widespread in the entire hospital 10-storey building that had 704 beds and 3004 rooms. A focused environmental investigation of microbial growth within the building followed, revealing moderate to high levels of fungi on interior surfaces and air sampling results showed >1000CFU/m3 in most areas . The mycological goal of the building restoration project was to reduce microbial reservoirs and the control of fungi on all exposed surfaces to the lowest feasible level. All visibly colonized materials in the building were discarded and all fine dust on interior surfaces was removed by vacuuming and/or damp wiping. A long-active organosilicon antimicrobial, 3- trimethoxy silyl propyl dimethyl octadecyl ammonium chloride was selected to treat all surfaces throughout reconstruction. Re-evaluation of the facility at 5 months following restoration showed 12% of the indoor environment to be free of airborne fungi; 53% with <100 CFU/m3 of air and 35% with over 100 - 200 CFU/m3.

3. Effectiveness of Silane-quats in a Hospital Test

"Surface-Bonded Antimicrobial Activity of an Organosilicon Quaternary Ammonium Chloride"
A. J. ISQUITH, E. A. ABBOTT, AND P. A. WALTERS
Biomedical Research and Development Laboratory, Dow Corning Corporation, Midland, Michigan 48640
The hydrolysis product of 3-(trimethoxysilyl) propyl dimethyl octadecyl ammonium chloride exhibited antimicrobial activity against a broad range of microorganisms while chemically bonded to a variety of surfaces. The chemical was not removed from surfaces by repeated washing with water, and its antimicrobial activity could not be attributed to a slow release of the chemical, but rather to the surface-bonded chemical.

4. Comparison of Control & Prevention Methods

"Today's Prevalent Infection Threats - A Comparison of Control and Prevention Methods"
Kim Strong, Maritime Testing, Dartmouth, NS

Every day the news has the same headlines - another heath care facility is faced with a closure due to yet another problem with Clostridium difficile, methicillin resistant Staphylococcus aureus, Aspergillus fumigatus, Legionella pneumophila or something else. Health care environments, unfortunately, are little more than "germ condominiums" from the perspective of opportunistic infectious microbes, a myriad of places for bacteria, viruses and fungi to grow, reproduce or simply just survive. Risk associated with exposure to these organisms is really a function of only three factors - the virulence or potency of the organisms, the susceptibility or vulnerability of the individuals in the population and the probability of exposure. Reduce any one of these components to an acceptably low level and risk is reduced commensurately. This article focuses on reducing the probability of exposure.
Many of the environments with health care settings, such as doorknobs, light switches and other high-touch surfaces, are cleaned and disinfected frequently with a variety of cleaning and disinfection chemicals. Others are either simply not cleaned at all (such as the interior of ventilation systems and wall cavities) or are cleaned less often (such as computer keyboards, telephone buttons and elevator controls). Our ability to control the growth and survival of microbes - and reduce exposure - has become dependent in part upon the cleaners and disinfectants that we use, both how they work and how often they are used.
The cleaners - or antimicrobial and disinfection agents - that we use can be broadly divided into two main groups, bound and unbound. These terms refer to whether or not the antimicrobial has the capacity to molecularly bond to the surface on which it is applied (bound) or whether it simply is used as a "wash" or "coating" (unbound). An unbound chemical, such as ethyl alcohol, any of the quaternary ammonium compounds (quats), peroxide, formaldehyde, metal ions and other topical disinfectants, must be applied to and then diffuse or leach from the treated surface and be consumed by the microorganism to be effective. These chemicals are intended to act quickly and dissipate equally quickly to minimize the danger to humans and treated objects. Many, including those used routinely in health care environments to clean hard non-porous surfaces such as faucets, door knobs, light switches, etc are simply wiped away after a brief contact time or just evaporate. The microbes on the surfaces are killed upon contact. Others use the time release capsule approach and obtain a longer working life by burying the antimicrobial in a paint, glue, binder or other coating and counting on slow migration to the surface. However, these must diffuse away from the carrier and create a zone of inhibition in order to function properly. Once inside the organism, the chemical agent will either act like a poison, interrupting some key metabolic, or life sustaining process of the cell and causing it to die, or oxidize the cell, causing it to be digested away. Once the antimicrobial has dried or is depleted or has been washed away during regular maintenance, protection vanishes. This is why high touch surfaces must be cleaned routinely - the chemicals used have no lasting effect. This is not an unintended deficiency; instead, it is what they are meant to do. Microbes transferred

from their source to hands (hand washing is also extremely valuable in reducing germ transfer) and then to unprotected (but perhaps recently cleaned or disinfected) objects such as doorknobs are not destroyed by contact with the objects. Instead, they remain there until they die or become non-viable, are removed at a subsequent cleaning or are transferred to another individual. It is this transfer of viable microbes that, if prevented or controlled, can lower risk by lowering frequently of exposure.

After application, unbound antimicrobials buried within carriers continue to diffuse or leach from the treated surface. As this diffusion continues, the concentration of the active ingredient eventually becomes diluted below effective levels. Under these conditions, microorganisms have the ability to adapt or build up a tolerance to these particular antimicrobials. Highly resistant strains can develop that are immune to what was once an effective dose.

The mode of action of some unbound chemicals, especially strong oxidizers such as accelerated peroxide and concentrated bleach, renders then unsuitable for use on porous surfaces including textiles.

A bound antimicrobial agent remains chemically attached to the surface on which it is applied. It functions by interrupting the organism's delicate cell membrane. This prevents microorganisms from carrying on vital life processes. This antimicrobial acts on contact with organisms and can do so again and again. One can think of the bound antimicrobial like a sword that is capable of repeated use. In comparison, a conventional antimicrobial treatment is more like a gun with limited ammunition. Since a bound antimicrobial is fixed to the surface it continually operates at full strength. This means the genetic adaptation process, which is an inherent problem with conventional antimicrobials, cannot and does not occur with a bound antimicrobial.

The chemistry of these products is unique. Typically, a conventional quaternary ammonium salt is chemically spliced to a silane molecule, resulting in a highly active molecule that has both tenacious bonding capabilities as well as excellent antimicrobial properties. Once applied to a target surface it initially bonds to the surface on all available receptor sites (principally H+). Afterward, stable bonds between remaining OH sites on the molecule and the positive charge on the nitrogen atoms (N+) form, resulting in the creation of a large co-polymer involving the target and the organo-silane. Since there is no unused residue once the water evaporates, there is no dislodgeable residue and no odour, leaching, off-gassing, migration or diffusion of the molecule can occur.

On a doorknob, for example, antimicrobial protection is extended past the initial application and drying period and will continue to destroy microbes on contact until the surface is either covered with dirt or is abraded away. Since cleaning is routine in health care environments, occlusion by dirt and organic debris is extremely improbable.

On most high-touch surfaces with typical abrasion, the antimicrobial activity will be effective for about a year. On surfaces not routinely abraded, such as walls and fabrics, the protection can be essentially indefinite.

All conventional antimicrobials used legally in Canada, including quaternary ammonium salts, bleach, peroxides, alcohols, phenols, formaldehydes, paint formulations, etc., work on the basis of diffusion away from the treated surface. This promotes adaptation, loss of activity, leaching, diffusion, and creation of zones of inhibition. Quite simply, their effect is short-lived. Reactive organo-silane chemistry, however, is essentially permanent, and treated surfaces benefit from extended antimicrobial protection that can be measured in months and years.

Albert Einstein one said that we should look to methods to solve problems that were better than the methods that we used to create them. Reducing risk in health care environments can be augmented by using chemistries that permanently attach agents to the target surfaces, providing continuous protection that does not promote genetic adaptation by the organisms and that does not pose unnecessary risk to the ultimate organisms being protected - us.

5. A New, Durable Antimicrobial Finish for Textiles

"A New, Durable Antimicrobial Finish for Textiles"
Richard L. Gettings, Dow Corning Corporation, Midland, Michigan
Benny L. Triplett, Burlington Industries Inc., Greensboro, North Carolina

3-trimethoxy silyl propyl dimethyl octadecyl ammonium chloride)+ imparts a durable,antimicrobial finish to textiles. The finish protects the fabric against bacteria and fungi that cause deterioration. It also inhibits the growth of odor-causing bacteria in in-vitro tests. In vivo organoleptic tests confirm the practicality of this concept under actual use conditions on socks.

6. Air Scrubbing Using Silane-quats

MIT's anti-microbial 'paint' kills flu, bacteria
MIT News Office 4/28/09
Anne Trafton, News Office

Coating's polymers poke holes in the membranes that surround influenza viruses!

A new "antimicrobial paint" developed at MIT can kill influenza viruses that land on surfaces coated with it, potentially offering a new weapon in the battle against a disease that kills nearly 40,000 Americans per year.

If applied to doorknobs or other surfaces where germs tend to accumulate, the new substance could help fight the spread of the flu, says Jianzhu Chen, MIT professor of biology.

"Because of the limited efficacies with existing (flu) vaccines and antivirals, there's room for other, complementary approaches," said Chen, one of the authors of a report on the new material that appeared Nov. 13 in the online edition of the Proceedings of the National Academy of Sciences.

In a typical year, 200,000 people in the United States are hospitalized from influenza virus infection, and 36,000 of them die, according to the Centers for Disease Control. If an avian flu pandemic broke out, as many experts fear, the death toll could be in the millions. Most fatal flu cases occur in the elderly or in people with weakened immune systems.

Available flu vaccines are only 30 to 40 percent effective among those groups, and only 70 to 80 percent effective among healthy adults.

Influenza is spread when viruses released by an infected person accumulate on surfaces, where other people pick them up. Stopping the viruses before they infect people could prevent some flu cases, says Chen.

The new substance can do just that, by killing influenza viruses before they infect new hosts. The "antimicrobial paint," which can be sprayed or brushed onto surfaces, consists of spiky polymers that poke holes in the membranes that surround influenza viruses. Influenza viruses exposed to the polymer coating were essentially wiped out. The researchers **observed a more than 10,000-fold drop in the number of viruses on surfaces coated** with the substance, according to Alexander Klibanov, MIT professor of chemistry and bioengineering and the senior author of the paper.

Combating E. coli, too:

The polymers are also effective against many types of bacteria, including human pathogens Escherichia coli and Staphylococcus aureus, deadly strains of which are often resistant to antibiotics. For example, S. aureus causes serious problems in hospitals, where it can spread among patients and health care workers.

"In the U.S., more people die in hospitals of diseases they didn't have when they got to the hospital than from the disease that prompted them to go to the hospital in the first place," said Klibanov, who anticipates the new material would be useful in a hospital setting, as well as others where people congregate.

The new coating acts in a very different way from the many antibacterial products--such as soaps, sponges, cutting boards, pillows, mattresses and even toys--that are now on the market. Those products--which kill bacteria but not viruses--depend on a timed release of antibiotics, heavy metal ions or other biocides, a system that has many drawbacks, says Klibanov. Once all of the biocide has been released, the antimicrobial activity disappears.

Also, it can be harmful to release all of these biocides into the environment.

One of the benefits of the new polymer coating is that it is highly unlikely that bacteria will develop resistance to it, Klibanov said.

Bacteria can become resistant to traditional antibiotics by adjusting the biochemical pathways targeted by antibiotics, but it would be difficult for bacteria to evolve a way to stop the polymer spikes from tearing holes in their membranes.

"It's hard to develop resistance to someone sticking a knife in your body," Klibanov said.

In a prior experiment designed to test for resistance, 99 percent of bacteria that were exposed to a polymer-coated surface died.

The researchers then took the surviving one percent, let them multiply and again exposed them to the surface. They repeated the cycle 12 times, and each time, approximately 99 percent of the bacteria were killed, suggesting that the microbes were not becoming resistant. The MIT researchers are working with industrial and military partners such as Boeing and the Natick Army Research Center to develop the coatings for practical use.

Once the polymer coating is applied to a surface, it should last about as long as a regular coat of paint, Klibanov said. Accumulation of dead bacteria and viruses diminishes the effectiveness of the nanometer-sized polymer spikes, so the surface would need to be washed with soapy water every once in a while to remove dead microbes, he said.

Other authors of the paper are Jayanta Haldar, a postdoctoral associate in chemistry, and former MIT affiliates Deqiang An and Luis Alvarez de Cienfuegos.

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7. A Comparison of Antimicrobials for the Textile Industry

"A COMPARISON OF ANTIMICROBIALS FOR THE TEXTILE INDUSTRY"

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Antimicrobials are used on textiles to control bacteria, fungi, mold, mildew, and algae and the problems of deterioration, staining, odors, and health concerns that they cause. In the broad array of microorganisms there are both good and bad types. Control strategies of the bad organisms must include consideration of being sure that non-target organisms are not affected or that adaptation of microorganisms is not encouraged.

Microorganisms cause problems with textile raw materials and processing chemicals, wet processes in the mills, roll or bulk goods in storage, finished goods in storage and transport, and goods as they are used by the consumer. This can be extremely critical to a clean room operator, a medical facility, or a food processing facility, or it can be an annoyance and esthetic problem to the athlete or normal consumers. The economic impact of microbial contamination is significant and the consumer interests and demands for protection is at an all time high.

The term antimicrobial refers to a broad range of technologies that can provide varying degrees of protection for textile products against microorganisms. Antimicrobials are very different in their chemical nature, mode of action, impact on people and the environment, in-plant handling characteristics, durability on various substrates, costs, and how they interact with good and bad microorganisms.

The paper covers the full range of positive effects that antimicrobials bring to the textile industry and provides for a full discussion of the types and properties of antimicrobials.

8. Antimicrobial products in the textile industry

"AntiMicrobial Products in the Textile Industry"
Fibre2fashion.com

Introduction:

As far as health-related professions are concerned, protection from pathogens is a growing concern, and textiles with antimicrobial properties are becoming more desirable. Fungi or similar other insects are responsible for lethal infections and allergic reactions. Despite the production of antimicrobial textile products; three inherent problems remain:

- Demonstration of efficacy,
- Claiming efficacy in a manner that does not invite legal challenge and,
- Maintaining efficacy over the lifetime of the textile and through generations of microbial challenges.

These problems might be restated as how to test and present the results of the testing, how to make the effect durable, and how to avoid microbial resistance to the treatment. These problems combine so that in spite of the commercial and advertising potential, effective, durable, inexpensive, and safe biocidal textiles are not widely available in the market.

It is of note that one promising compound which has been appearing commercially in a variety of products has just encountered its first resistant
Organism.

Antimicrobial Technologies in Textiles:

Whether the performance or technical fabric is ultimately used outdoors, indoors, or on the body challenges such as microbial control, moisture management, odor control, elasticity, and even softness are prevalent. These challenges offer new opportunities to wisely seek technologies to address those needs - whether you are looking for a single or combination of features.

This discussion will address the considerations important in choosing the right finishes for your customer's performance needs, i.e. durability, ease of application, safety, and ultimate end-use performance requirements. Consumers' needs drive the product value chain and features of value make the margin difference for marketplace success.

The inherent properties of the textile fibres provide room for the growth of micro-organisms. Besides, the structure of the substrates and the chemical processes may induce the growth of microbes. Humid and warm environment still aggravate the problem. Infestation by microbes cause cross infection by pathogens and development odour where the fabric is worn next to skin. In addition, the staining and loss of the performance properties of textile substrates are the results of microbial attack. Basically, with a view to protect the wearer and the textile substrate itself antimicrobial finish is applied to textile materials.

Historical Account:

During World War II, when cotton fabrics were used extensively for tentage, tarpaulins and truck covers, these fabrics needed to be protected from rotting caused by microbial attack. This was particularly a problem in the South Pacific campaigns, where much of the fighting took place under jungle like conditions. During the early 1940's, the US army Quartermaster Crops collected and compiled data on fungi, yeast and algae isolated from textiles in tropical and subtropical areas throughout the world. Cotton duck, webbing and other military fabrics were treated with mixtures of chlorinated waxes, copper and antimony salts that stiffened the fabrics and gave them a peculiar odour. At the time, potential polluting effects of the application of, these materials and toxicity-related issue were not a major consideration. After World War II, and as late as the mid-to-late 1950.s fungicides used on cotton fabrics were compounds such as 8-hydroxygiunoline salts, copper naphthenate, copper ammonium fluoride and chlorinated phenols.

What Are Microbes?

Microbes are the tiniest creatures not seen by the naked eye. They include a variety of micro-organisms like Bacteria, Fungi, Algae and viruses. Bacteria are uni-cellular organisms which grow very rapidly under warmth and moisture. Further, sub divisions in the bacteria family are Gram positive (Staphylococcus aureus), Gram negative (E-Coli), spore bearing or non spore bearing type. Some specific types of bacteria
are pathogenic and cause cross infection. Fungi, molds or mildew are complex organisms with slow growth rate. They stain the fabric and deteriorate the performance properties of the fabrics. Fungi are active at a pH level of 6.5. Algae are typical micro-organisms which are either fungal or bacterial. Algae require continuous sources of water and sun light to grow and develop darker stains on the fabrics.

The hospital and healthcare systems are challenged by the presence of microorganisms and the negative effects they cause. Deterioration, defacement and odors are all dramatic effects which occur from the microbial contamination of surfaces as varied as uniforms and medical non-woven fabrics to medical devices and hard surfaces i.e., walls, ceilings, and air systems. Most significantly, these surfaces can act as
microbial "harbors and transfer site (vectors)," offering ideal environments for the proliferation and spread of microorganisms that are harmful to buildings, textiles, and humans. The ability to make microbial resistant surfaces in a healthcare environment has advantages in many applications.

In spite of the many precautions taken to prevent or reduce the transmission of harmful organisms in hospitals, such as hand-cleaning, housekeeping, and laundry protocols, the risk of cross contamination of surfaces and textiles to patients and staff is considerable. Any textile material and hard surface in a hospital environment is a potential carrier of infectious agents such as bacteria, fungi, and yeast. The only effective strategy for reducing such infections and the conditions for reservoirs of organisms where resistance is stimulated is to reduce the dose of microorganisms throughout the healthcare complex using safe persistent antimicrobial technologies to treat such surfaces and to maintain the highest standards of hygiene and use protocols for antibiotics.

Major Challenges:

The problems of allergy and asthma are steadily increasing. One of their major causes is the dust mite, which thrives in the bedding, carpets and furniture of every home. But, today, textile treatments are
available. The result - a more comfortable home for those who suffer from these chronic sicknesses.

Allergies and asthma seem to be an increasing phenomenon of our everyday lives. We all know at least one
person who suffers from these chronic problems. In some parts of the world over 40% of the population
shows allergy symptoms. India has been identified as one of the 'hot spots' for asthma around the world.

The explanation for this increase is mostly related to the fact that we now live cleaner lives in an air-conditioned world. We might not have to deal with serious diseases like smallpox or polio. Instead, we have a series of smaller complaints, which are perhaps related to our lifestyles. Asthma can be triggered because of a number of reasons. However, in the last few years, we have realized that the cause for a significant amount of allergies and asthma can be attributed to one creature —the house dust mite. The World Health Organization has named asthma as one of the major health problems of the current period. The prevalence of dust mites is no unique phenomenon. They exist on every continent, in every country and in every house.

They include:

- Runny or stuffy nose, chronic rhinitis,
- Itchy and watery eyes,
- Sneezing,
- Asthma attacks,

- Wheezing coughs,
- Shortness of breath,
- Signs of allergy while making the bed,
- A general feeling of being unwell, without being extremely ill

Antimicrobial Treatment:

By incorporating this type of finish into textiles and fabrics, wearers will be protected from microbiological attack. There are different kinds of antimicrobial finishes, appropriate for different applications and levels of protection. One major application of antimicrobial finish is in the medical field. Medical applications demand powerful bactericidal antimicrobials that will perform quickly to help maintain sterile environments. In case of institutional applications such as uniforms and hotel/ restaurant fabric, the antimicrobial would only be required to have a bacteriostatic effect to control stains and odour. Apparel and home textile applications such as active wear, bed linen, hosiery, underwear, carpeting, etc, will also use antimicrobial activity to control odour and staining. One major application of antimicrobial finish is in the medical field—to help maintain sterile environments.

Antimicrobial treatment for textile materials is necessary to fulfill the following objectives:

- To avoid cross infection by pathogenic micro organisms;
- To control the infestation by microbes;
- To arrest metabolism in microbes in order to reduce the formation odour; and
- To safeguard the textile products from staining, discolouration and quality deterioration.

It is neither possible nor desirable to remove all the dust mites from our environment. They are an important part of the ecosystem. However, it would be useful to eliminate them from the immediate surroundings of those suffering from asthma. This could be done by removing all possible homes for the mites, such as bedding and carpets. But this is a rather drastic measure. Just because a person suffers from an allergy, he/she does not have to sleep in a bare cell. Nowadays, there are treatments available for textiles and carpets, which create an inhospitable environment for the dust mite. This stops the dust mites from inhabiting these locations, thereby, keeping them relatively free of the allergens. The textile treatments used against dust mites have a long history of use as anti-fungal agents. There seems to be a relationship between fungal protection and the inhibition of dust mites. There are a number of theories, which talk about the exact nature of this relationship, but none has been clearly proven. However, it can be demonstrated that anti-bacterial treatments, which are not anti-fungal, have no effect on the dust mite. In addition, it is important to note that not all anti-fungal products have anti-dust mite properties.

Requirements for Antimicrobial Finish:

Textile materials in particular, the garments are more susceptible to wear and tear. It is important to take into account the impact of stress strain, thermal and mechanical effects on the finished substrates.

The following requirements need to be satisfied to obtain maximum benefits out of the finish:

- Durability to washing, dry cleaning and hot pressing;
- Selective activity to undesirable microorganisms;
- Should not produce harmful effects to the manufacturer, user and the environment;
- Should comply with the statutory requirements of regulating agencies;
- Compatibility with the chemical processes;
- Easy method of application;
- No deterioration of fabric quality;
- Resistant to body fluids; and
- Resistant to disinfections/sterilization.

Antimicrobial Finishing Methodologies:

The antimicrobial agents can be applied to the textile substrates by exhaust, pad-dry-cure, coating, spray and foam techniques. The substances can also be applied by directly adding into the fibre spinning dope. It is claimed that the commercial agents can be applied online during the dyeing and finishing operations. Various methods for improving the durability of the finish include:

- Insolubilisation of the active substances in/on the fibre;
- Treating the fibre with resin, condensates or cross linking agents;
- Micro encapsulation of the antimicrobial agents with the fibre matrix;
- Coating the fibre surface;
- Chemical modification of the fibre by covalent bond formation; and
- Use of graft polymers, homo polymers and/or copolymerization on to the fibre.

Application of Antimicrobial in different sectors:

- Paints & Coatings
- Plastics
- Consumer Products
- Food & Beverage Processing
- Medical & Healthcare
- Restaurants & Loading
- Others

Benefits of Antimicrobial Textiles:

A wide range textile product is now available for the benefit of the consumer. Initially, the primary objective of the finish was to protect textiles from being affected by microbes particularly fungi. Uniforms, tents, defence textiles and technical textiles, such as, geotextiles have therefore all been finished using antimicrobial agents. Later, the home textiles, such as, curtains coverings, and bath mats came with antimicrobial finish. The application of the finish is now extended to textiles used for outdoor, healthcare sector, sports and leisure. Novel technologies in antimicrobial finishing are successfully employed in non-woven sector especially in medical textiles. Textile fibres with built-in antimicrobial properties will also serve the purpose alone or in blends with other fibres. Bioactive fibre is a modified form of the finish which includes chemotherapeutics in their structure, i.e. synthetic drugs of bactericidal and fungicidal qualities. These fibres are not only used in medicine and health prophylaxis applications but also for manufacturing textile products of daily use and technical textiles. The field of application of the bioactive fibres includes sanitary materials, dressing materials, surgical threads, materials for filtration of gases and liquids, air conditioning and ventilation, constructional materials, special materials for food industry, pharmaceutical industry, footwear industry, clothing industry, automotive industry etc.

9. Wound Care and Silane quats

"Wound Care – Antimicrobial Treated Fabrics as Protective and Therapeutic Materials"
W. Curtis White, Robert A. Monticello.

Skin, the largest organ of the human body, is a complex mixture of functional and protective cells. When the skin is compromised by intentional, physiological, or traumatic means, a wound is created.

Wound protection must include protections against physical, chemical, and microbiological stresses. Combinations of external and systemic therapies and barrier coverings/coatings have been used for centuries.

This paper presents a review of the physiological problems and available solutions for all types of wounds. Specific examples of fabrics treated with antimicrobial treatments and their protective and therapeutic benefits will be presented. Risks and benefits of various antimicrobial technologies will be discussed.

10. Wound Care and Silane quats

"Bacterial Contamination on Hospital Pagers"
Singh D, Kaur H, Gardner WG, Treen LB.
Department of Internal Medicine, Akron General Medical Center, Ohio 44307, USA.
We assessed the bacterial contamination of the pagers of healthcare personnel and the efficacy of disinfection with 70% isopropyl alcohol. Microorganisms were isolated from all pagers; 21% yielded Staphylococcus aureus, of which 14% were methicillin resistant. Cleaning with alcohol reduced the total colony count by an average of 94%. Bacterial load varied by healthcare worker group and service assignment.

11. Cross Contamination and HAI

"Prevention of Cross Transmission of Microorganisms Is Essential to Preventing Outbreaks of Hospital-Acquired Infections"
David Schwegman, MD., Assistant Professor of Medicine, Emory University

Hospital-acquired infection outbreaks may be prevented by providing single-patient-use disposable blood pressure cuffs that will remain with that patient from admission until discharge from the hospital before being discarded. Single-patient-use disposables may prevent hospital-acquired infections that result from use of devices by multiple patients.

Total Health Care Cost from Hospital-Acquired Infections

- Over 99,000 deaths per year in the United States
- Increased ICU stay 8 days
- Increased average hospital stay between 7.4 and 9.4 days
- Total dollar cost between $4.5 and $5.7 billion
- Average cost per infection of $13,973
- Increased total cost per patient who survived approximately $40,000

12. World Health Organization - Prevention of hospital-acquired infections

A PRACTICAL GUIDE
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	Katan Technologies Products				Competitors					
Retail Brand	**Biospada**	**Khloros**	**Denki**	**Wado**						
Commercial Brand	**Si**	**Cl**	**Ag**	**Cu**						
Technology	**(SiQUAT)**	**Benzalkonium Chloride**	**Silver Salts**	**Micro-Copper, Nano-Silver**	**Heavy Metals**	**Triclosan**	**Phenols**	**Alcohol**	**Bleach**	**Oxidizing Agents**
Toxicity Rating	**Very MILD**	**Mild**	**Mild**	**Mild**	HIGH	GROWING CONCERNS	HIGH	MEDIUM	MEDUIM	VARIES
Odour Reduction	**YES**	**NO**	**YES**	**YES**	YES	YES	YES	NO	YES*	YES
Durability	**Essentially PERMANENT**	**NO**	**Up to 24 Hours**	**DURABLE**	VARIES	NO	NO	NO	NO	NO
Green	**YES**	**YES**	**YES**	**YES**	NO	NO	NO	NO	NO	NO
Prevents Super Bugs	**YES**	**NO**	**NO**	**NO**	NO	NO	NO	NO	NO	NO
Prevents Cross-Contamination	**YES**	**NO**	**POSSIBLE**	**POSSIBLE**	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE	POSSIBLE	NO
Water-Based	**YES**	**YES**	**YES**	**NO**	NO	NO	NO	YES	YES	VARIES

* distinctive residual chlorine odour

Independent Test Results

Organism	Bacteria Reduction	After 14 Days (%)	After 28 Days (%)
Staphylococcus aureus	99.98	99.97	99.98
Pseudomonas aeruginosa	99.94	99.96	99.96
Escherichia coli (E-coli)	99.99	99.98	99.98
Proteus vulgaris	99.92	99.93	99.93
Methicillin resistant staphylococcus aureus (MRSA)	99.99	99.98	99.96
Vancomycin resistant Enterococcus (VRE)	99.97	99.97	99.96
Legionella pneumoniae	99.99	99.99	99.97
Salmonella cholerae suis	99.92	99.94	99.94
Cryptosporidium parvum (oocysts)	98.45	98.45	98.44
Influenza A2 (Asian)	99.91	99.94	99.94
Citrobacter freundii	99.99	99.98	99.98
MS2 bacteriophage	99.96	99.96	99.99

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