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Long-Lasting Antimicrobial and Antiviral Surface Coatings

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The Defense Systems Information Analysis Center (DSIAC) was asked to determine if commercial or government off-the-shelf, long-lasting antiviral surface coatings exist. DSIAC researchers compiled relevant information as of April 2020 and reached out to subject matter experts from U.S. Department of Defense (DoD) laboratories working on related efforts. Multiple commercial and government antimicrobial or antiviral surface coatings and DoD-funded research projects with the potential to protect against the COVID-19 virus are compiled in this report, as well as a general introduction to relative terms and technologies. However, these products should still be verified through a third-party, independent laboratory for testing to ensure effectiveness against SARS-CoV-2. In addition, aging tests should be performed to ensure that the coating retains its antimicrobial/antiviral properties over time and through normal wear. Finally, testing vs. the SARS-CoV-2 virus (rather than a normally acceptable substitute) is necessary to be certain that the coating inactivates or kills the virus.

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A chief service of the DoD IACs is free technical inquiry (TI) research, limited to 4 research hours per inquiry. This TI response report summarizes the research findings of one such inquiry jointly conducted by DSIAC.

ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) was asked to determine if commercial or government off-the-shelf, long-lasting antiviral surface coatings exist. DSIAC researchers compiled relevant information as of April 2020 and reached out to subject matter experts from U.S. Department of Defense (DoD) laboratories working on related efforts. Multiple commercial and government antimicrobial or antiviral surface coatings and DoD-funded research projects with the potential to protect against the COVID-19 virus are compiled in this report, as well as a general introduction to relative terms and technologies. However, these products should still be verified through a third-party, independent laboratory for testing to ensure effectiveness against SARS-CoV-2. In addition, aging tests should be performed to ensure that the coating retains its antimicrobial/antiviral properties over time and through normal wear. Finally, testing vs. the SARS-CoV-2 virus (rather than a normally acceptable substitute) is necessary to be certain that the coating inactivates or kills the virus.

Contents

1.0 TI Request

1.1 INQUIRY

What antiviral surface coatings are commercially available that last weeks/months instead of hours/days?

1.2 DESCRIPTION

The inquirer is interested in commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) solutions.

2.0 TI Response

The Defense Systems Information Analysis Center and Texas Research Institute Austin (TRI Austin) researchers performed literature searches and contacted leading U.S. Department of Defense chemical, biological, radiological, nuclear, and explosive materials research organizations for antimicrobial and antiviral surface coating technologies that could be potentially formulated to protect against the COVID-19 virus. A compilation of surface coating technologies identified as of April 2020 is discussed in this report.

2.1 INTRODUCTION

Before beginning, it is appropriate to make some distinctions between some of the terms used to describe the coatings.

2.1.1 Antimicrobial

The term antimicrobial can be used in a variety of product claims across industries. As such, products that claim antimicrobial properties with a public or nonpublic health claim must go through appropriate testing by product type to demonstrate efficacy and then approval by the Environmental Protection Agency (EPA).

Coatings that contain antimicrobial properties can inhibit the growth of these microorganisms, protecting the film itself from degradation. In addition, antimicrobial agents inhibit the growth of bacterial odor. Antimicrobial coatings often inactivate viruses. Antimicrobial products kill or slow the spread of microorganisms. Microorganisms include bacteria, viruses, protozoans, and fungi, such as mold and mildew. As antiseptics, antimicrobial products are used to treat or prevent diseases on people, pets, and other living things.

All antibiotics are antimicrobials, but not all antimicrobials are antibiotics. In contrast, the term "antimicrobials" includes all agents that act against all types of microorganisms—bacteria (antibacterial), viruses (antiviral), fungi (antifungal), and protozoa (antiprotozoal).

2.1.2 Antibacterial

A type of antimicrobial, antibacterial agents is used to inhibit the growth of bacteria (not necessarily including viruses). However, in paint, antibacterial agents typically inhibit only the growth of the common microbes that make up harmful bacteria, thus only protecting the paint film itself.

2.1.3 Microbicidal

Generally speaking, microbicidal substances or compounds kill microscopic organisms on a surface. Paints formulated with these properties are designed to kill microorganisms, such as bacteria or other disease-causing microorganisms, on painted surfaces. Any product that has health-related claims to kill harmful microorganisms must be registered with the EPA.

There is significant overlap between these classes, and sometimes these explicitly say they kill viruses and only mention bacteria. Many coatings purport to be antibacterial. An antibacterial label is not necessarily the same as antiviral. Another thing to consider is that products presently available are not likely to have been tested using the SARS-CoV-2 virus (which is an enveloped virus). Norovirus and influenza have been the most popular targets for antiviral (or virucidal) coatings, as influenza infects millions of people each year and norovirus is responsible for roughly half of United States food-borne disease outbreaks each year. However, SARS-CoV-2 is an enveloped virus, whereas norovirus is nonenveloped. Studies should be conducted on the virus or, at the very least, a similar type (enveloped) in question to ensure that any candidate coating is capable of inactivating (defined as not removing the virus but rendering it noninfective) the virus. As a result, caution must be exercised, and independent testing of the efficacy of any coating to kill/inactivate SARS-CoV-2 is very highly recommended.

2.1.4 Testing

There are several standards of testing that many of the companies marketing these coatings must follow:

1. International Organization for Standardization 22196 (Measurement of Antibacterial Activity on Plastics and other Nonporous Surfaces).
2. JIS Z 2801 (Japanese Industrial Standard for Test for Antimicrobial Activity and Efficacy).
3. American Association of Textile Chemists and Colorists (AATCC) Test Method 100-2012.

The American Society for Testing and Materials (ASTM), or ASTM International, also has a test method (ASTM E2149-13a - Standard Test Method for Determining the Antimicrobial Activity of Antimicrobial Agents Under Dynamic Contact Conditions), but this method is not referenced often in the marketing material from the companies discussed later in this report.

2.1.5 Potential Antiviral Materials Systems

There are several potential materials that may be leveraged as nanoparticles within and for use as an antiviral coating. Nanoparticles of different materials, such as metal nanoparticles, carbon nanotubes, metal oxide nanoparticles, and graphene-based materials, have demonstrated enhanced antimicrobial and antiviral activity. The use of inorganic nanomaterials when compared with organic antimicrobial agents is also desirable due to their stability, robustness, and long shelf life. At high temperatures/pressures, organic antimicrobial materials are found to be less stable compared to inorganic antimicrobial agents. The various antimicrobial mechanisms of nanomaterials mostly attribute to their high specific surface area-to-volume ratios and their distinctive physicochemical properties.

Viruses constitute a group of heterogeneous and much simpler organisms. They range in size from 100 to 300 nm and are much smaller than bacteria. Viruses are unique in that they have no independent metabolic activities and rely solely on infecting living hosts to reproduce. Unlike all other life, viruses may contain either DNA or RNA as genetic materials, but not both.

The nucleic materials are surrounded by a protein coat to protect them from harmful agents in the environment. The protein coat also provides the specific binding sites necessary for attaching the virus to its host. Some viruses also contain an outer envelope made up of lipids, polysaccharides, and protein molecules. The lipids and polysaccharides allow a virus to fuse with a host cell and thus gain entry.

A virus without the outer envelope infects a cell in quite a different manner. Infection is initiated by the attachment of a specialized site on the surface of the protein coat of the virus onto a specific receptor site on the surface of the host cell.

Once this binding is complete, viruses can release genetic materials into the host cell and take advantage of the machinery of the host cell to reproduce and assemble themselves. These newly-produced viruses are now ready to infect other cells.

Therefore, one of the key processes to disable viruses is controlling their surface structure, especially their binding sites, so they can no longer recognize the receptor site on the host cells. As many types of nanocoatings attack most effectively on the virus's surface, these represent an excellent viable technology to destroy virus surface structure.

2.1.6 Metallic Containing Coatings

Martinez-Abad et al. [1] discussed how silver-infused polylactide films could be used to inactivate salmonella and feline calicivirus (FCV) for fresh-cut vegetables. In this work, as expected, higher concentrations of silver (Ag) produced higher antibacterial and antiviral effects, but that the FCV was less susceptible to Ag than the salmonella. In addition, the substrate examined (vegetable) seemed to also have an effect on the results.

In addition, Hodek et al. [2] discussed the antimicrobial effects of nano-Ag, copper (Cu), and zinc (Zn) cations against human immunodeficiency virus (HIV) and other enveloped viruses.

Other examples of metals and metallic nanoparticles exhibiting antimicrobial effects are found in other journal articles by Elechiguerra et al. [3] and Galdiero et al. [4].

2.1.7 Nonmetallic Containing Coatings

Hodek et al. [2] also discussed the effects of several other nonmetallic hybrid coatings. They found that photoactivation of titanium dioxide (TiO_2) by ultraviolet (UV) generates reactive oxygen molecules on the surface of TiO_2 and was shown to effectively inactivate influenza A, HIV-1, and murine norovirus. Halogen and interhalogen TiO_2 nanoparticles, except for chlorinated adduct, completely inactivated bacteriophages MS-2, ψ-X174, and PRD-1, showing that oxidizing potential can be generated without requiring UV photoactivation. Similarly, metal oxide nanoparticles, cerium oxide (CeO_2) and aluminum oxide (Al_2O_3), and their halogen adducts exhibited excellent virucidal activities against bacteriophages. Similar results were found by Peddinti et al. [5]. Some of these results also explored photochemistry, but the wavelength needed was in the visible spectrum, which is considerably safer than the UV spectrum. Another set of results discusses using Ti- and Zn-oxides as antimicrobial coatings with generally positive results, provided that activation by UV light is applied [6].

In addition, quaternary ammonium cations, commonly called “quats,” are very promising to inactivate the virus and are well proven [7]. Other studies have also found similar results as those for metallic oxides, such as copper oxide (CuO), zinc oxide (ZnO), gold (Au) on silicon (Si), and copper iodide (CuI) [8, 9].

2.1.8 Organic-Based Coatings

Haldar et al. [10] found that applying a coating of ranched or linear N,N-dodecyl methylpolyethylenimines (PEIs) and certain other hydrophobic PEI derivatives to a glass slide enabled it to kill influenza virus with essentially a 100% efficiency (at least a 4-log reduction in the viral titer) within minutes, as well as the airborne human pathogenic bacteria Escherichia coli (E. coli) and Staphylococcus aureus (staph) [10]. In addition, work has been done showing the ability of tea tree and eucalyptus oils at inactivating influenza virus [11].

2.2 AVAILABLE COTS AND GOTS COATINGS

2.2.1 Allied Bioscience Antimicrobial Coating

Allied BioScience, in conjunction with the Emergency Controls Division of North American Fuel Tanks, Inc., has developed a transparent, odorless, continuously-active antimicrobial coating that kills microbes on surfaces and continues to prohibit microbial growth for up to 12 weeks after one application. The coating is applied using an electrostatic sprayer to ensure 100% surface coverage and can be applied to as much as 3,400 ft^2 per hour. The coating carries the lowest toxicity rating given out by the EPA [12, 13].

2.2.2 Sherwin Williams Antimicrobial Paint

Sherwin Williams markets a product called Paint Shield microbicidal paint, which claims to kill 99.9% of staph, E. coli, MRSA (methicillin-resistant Staphylococcus aureus), VRE (Vancomycin-resistant Enterococcus), and Enterobacter aerogenes on painted surfaces within 2 hours of exposure. This paint also claims to continue killing 90% of bacteria for up to 4 years when the integrity of the surface is maintained.

The paint passed EPA test protocols conducted by third-party labs and underwent scrubbing tests and repeated exposure tests to ensure that despite exposure to normal wear and tear, cleaning and scrubbing, it maintains its effectiveness (for up to 4 years when the integrity of the surface is maintained).

It is applied like interior paint and can be applied on ceilings, walls, doors, and trim. Originally developed for health care facilities, athletic facilities, schools, and other specialized business settings, Paint Shield is also ideal for any residence, especially in the bathroom, kitchen, and laundry room. As with any interior paint, two coats are required over a previously-primed or painted surface, and it can be applied with traditional paint brushes and rollers.

The active ingredient is a quaternary ammonium compound (alkyl dimethyl benzyl ammonium chloride), commonly known in the industry as “quat” [14].

2.2.3 ZeoVation Agisalus

ZeoVation’s Agisalus is an advanced, controlled-release antimicrobial treatment for paints and coatings. It can be easily and cost-effectively manufactured into all types of solvent, water-based, liquid, oil, or powder paints and coatings, including the following:

- General industrial coatings
- Decorative coatings
- Specialty coatings
- Specialty inks
- Varnishes

Agisalus provides a lasting and effective protection against harmful bacteria, mold, fungi, and viruses by up to 99.99%. Agisalus, a colloidal suspension, is effective against gram-positive and gram-negative bacteria (including methicillin- and vancomycin-resistant bacteria) [15]. ZeoVation includes performance charts on their website, though the information supplied does not mention how long the coating lasts as an antimicrobial.

2.2.4 Nano Graphene Inc. Graphene-Based Coating

Nano Graphene Inc., doing business as GrapheneCA, a commercial-scale graphene producer and developer of graphene-based technology, is developing a graphene-based coating with antibacterial and antiviral properties.

GrapheneCA's coating is being formulated to be applied in the form of paints and varnishes to walls and surfaces of public settings that are high-risk areas for microorganisms such as bacteria and viruses, including shopping malls, metro stations, airports, and event halls. The formula has been shown in laboratory tests to block the metabolism of microorganisms by restricting cellular respiration and cell division. Furthermore, assessments show that microorganisms die when coming into contact with surfaces covered with the coating's components.

GrapheneCA intends to commence independent testing of the coating's antibacterial and antiviral properties and is targeting commercialization of the coating as early as the third quarter of 2020. The formulation of this compound is proprietary [16, 17].

2.2.5 Alistagen Corporation Caliwel BNA

Alistagen Corporation's Caliwel bi-neutralizing agent (BNA) is a nontoxic, natural mineral-based, antimicrobial, antiviral surface coating that has been EPA approved since 2002. Recently, it was proven to be 99.9% effective against more than 20 microbes that cause influenza, asthma, allergies, staph infection, polio, hepatitis, cholera, and Legionnaires' disease and has been found effective against these microbes and the influenza virus for up to 6 years. Caliwel works through its BNA that harnesses the high-alkalinity, germ-killing power of calcium hydroxide ($Ca[OH_2]$) in a new multipatented, microencapsulated formulation. The encapsulation process makes the calcium hydroxide coating resistant to degradation for up to 6 years while maintaining its antimicrobial effectiveness. Caliwel was researched and developed mostly at the Southwest Research Institute in San Antonio, TX, and was engineered for use in hospitals, schools, and nursing homes. Alistagen Chief Executive Officer noted that Caliwel BNA represents a breakthrough in killing microbes responsible for numerous infectious diseases, including potentially SARS-CoV-2 [18].

2.2.6 Nonova Hygiene+TM (India)

NANOVA HYGIENE+TM, created by Nova Surface-Care Centre Pvt. Ltd., is marketed as an antimicrobial coating for surfaces like fabrics, plastics, metals, and concretes and contains a cocktail of nonmigratory quats and positively-charged Ag as bioactive nanoparticles, which are dispersed into binder polymers. This antimicrobial coating also shows extremely low surface energy value (>20 mN/m) and behaves as an omniphobic surface by repelling water and oil together.

In initial antiviral tests of NANOVA HYGIENE+ TM, MS2 bacteriophage (poliovirus), a small nonenveloped RNA virus of the family Leviviridae, was used. The results show an antiviral efficacy of 99.9% after 2 hours of contact with the surface AATCC 100-2012. An antiviral test is in process to establish its efficacy on inactivation of COVID-19 on different surfaces to stop the secondary spread from various surfaces to living cells through touch [19].

2.2.7 Cufitec

Cufitec is sold by NBC Meshtec, Inc. (out of Hino, Japan) as an antiviral and antibacterial technology that utilizes nanoparticles of a monovalent copper compound. It can be processed for use in a variety of materials (applied to a matrix, blended into plastic, or mixed into a solution) and used in wide range of applications [20].

2.2.8 Sobinco Nanocoat

Nanocoat is an antiviral, antibacterial, and antifungal surface treatment of aluminum doors and window handles developed in a joint effort between Sobinco (Belgium), daughter company STA, and the biogenetic laboratories of the University of Coimbra (Matera, Portugal). In this process, the aluminum surface is treated with a silica-based nanoparticle coating with a bioactive agent that upon direct contact with a bacteria, virus, or fungus, perforates the cell membrane and quickly kills it. The coating uses silica instead of silver ion, helping it last longer by using a small amount of active substance. Anodized aluminum pieces with Nanocoat were tested in an independent laboratory in Germany (Hohenstein Institute) and obtained the highest score in terms of antiviral activity [21].

2.2.9 U.S. Naval Research Laboratory (NRL)

NRL has developed a series of biocides that, when formulated with the proper resin systems, produce coatings and polymers that kill a variety of bacteria, molds, and viruses on contact. The advantages of the NRL biocide stems from the novel design of the molecule, with one end being hydrophobic and the other hydrophilic. This structure causes the biocide to preferentially migrate to the surface, where it is most effective, while the resin or coating is still liquid. The structure also greatly reduces removal by leaching once dried or cured [22].

Scientists from NRL have recently invented a class of potentially highly-mobile, self-spreading biocides that combine the wetting and spreading properties of silicone fluids with biocidal functionalities of ammonium salts. The biocidal fluid may consist of three distinctive components—a polydimethylsiloxane (PDMS) block, an optional extender block, and a biocidal moiety. The patented technology is available via patent license agreement to companies that would make, use, or sell it commercially.

2.2.10 AFRL/UES, Inc. Halamine

The technology developed by AFRL adds rapid, potent, and broad-spectrum antimicrobial activity to fabrics and surfaces. In simple terms, this chemical treatment turns materials into "bleach batteries" that can be charged with simple household bleach and then release chlorine when contacted by biological agents. The chlorine content of these materials is rechargeable. This technology is exceptionally expeditionary, and strong antimicrobial materials can be made from common chemicals (e.g., vinegar, bleach, and wool or silk) on-site, without the need for expensive equipment. More sophisticated variants of this technology can be manufactured to give multiple and long-lasting modes of antibiotic capability. Materials have been successfully incorporated into paints and painted surfaces demonstrated to destroy biological agents. This represents one of the few materials that can deactivate even the hardiest of biological agents and bacterial spores and within minutes [23–26]. The following are three peer-reviewed journal articles related to the technology and the government and business contacts:

1. "Sporicidal/Bactericidal Textiles via the Chlorination of Silk," by M. B. Dickerson, W. Lyon, W. E. Gruner, P. A. Mirau, J. M. Slocik, and R. R. Naik [24].
2. "Unlocking the Latent Antimicrobial Potential of Biomimetically Synthesized Inorganic Materials," by M. B. Dickerson, W. J. Lyon, W. E. Gruner, P. A. Mirau, M. L. Jespersen, Y. Fang, K. H. Sandhage, and R. R. Naik [25].
3. "Keratin-Based Antimicrobial Textiles, Films, and Nanofibers," by M. B. Dickerson, A. A. Sierra, N. M. Bedford, W. J. Lyon, W. E. Gruner, P. A. Mirau, and R. R. Naik [26].

A paper published in *Biomacromolecules* supports the use of antimicrobial *N*-halamine polymers and coatings for use due to its effectiveness against a broad spectrum of microorganisms, long-term stability, regenerability, safety to humans and the environment, and low cost. Three main approaches of preparation are discussed—polymerization, generation by electrochemical route with proteins and monomers, and grafting with precursor monomers. Examples of the application of *N*-halamines in water treatment, paints, healthcare equipment, and textile industries are discussed [27].

2.2.11 U.S. Air Force Civil Engineering Center at Tyndall Air Force Base (AFB)

Researchers at the Air Force Civil Engineer Center at Tyndall AFB, FL, have formal background education, relevant technical expertise, and a history of diverse and productive work in fundamental science and technology development to address chem-bio threats. The technical expertise that provided the summarized work are available on-site to extend concepts or provide other relevant support. A report of research snapshots and relevant references to work done and led by teams at Tyndall AFB was delivered to the inquirer; the most relevant are summarized next [28].

The Air Force Materials and Manufacturing Directorate and Joint Science and Technology Office – Defense Threat Reduction Agency funded research involving approaches that integrate molecules of the innate immune system and nanoscale inorganic materials to create novel antimicrobial composites and self-sterilizing coatings. This work, done at Tyndall AFB, involved exploring two approaches for application—antimicrobial peptides and nanoparticulate silver. The results of the study will hopefully assist in accelerating these types of materials to commercial production and ultimately contribute to biological warfare mitigation in the future [28, 29].

Additional projects furthered technical transition of laboratory materials and chemistries against chem-bio protection requirements. Active surface coatings and textiles are primary application spaces. The approach is directly transferable to personal protective equipment and contact surfaces in triage or health care settings. There are additional decontamination chemistries that are applicable to threat and pathogen neutralization. The team also has pilot scale processing capability to treat cloth bolts in reel-to-reel platform. Furthermore, there are active agreements with industry partners for promoting and transitioning the laboratory material concepts.

Dr. Jeff Owens, a senior Air Force chemist, helped to invent an antimicrobial coating that focuses on deactivating toxins; that effort has resulted in a novel method for forming a coating against toxins which renders them benign. The coating compound, made up of a glycoluril function group and a siloxane monolayer precursor group, is applied to a surface under microwave irradiation. The surface material may be a fabric or cloth from cotton, polyester, nylon, wool, rayon, or other materials [28, 30]. Dr. Owens and the U.S. Air Force Civil Engineering Center partnered with Theriax, LLC, to develop and produce a coating preservative to prevent in-can spoilage from bacteria and mold, for which a patent application was filed in 2019 [28, 31]. The partnership is utilizing chloramide treatments to create paint formulations based on proven decontaminants to provide post application protection from bacteria, viruses, and mold, particularly for use in hospital settings [28].

Multiple other projects that include chem-bio decontamination and coating research performed at Tyndall AFB are further discussed in the attachment supplied to the inquirer [28].

2.2.12 MicrobeCare

MicrobeCare XLP is a commercially-available, spray-on agent that is advertised to covalently bond to surfaces and provide a long-lasting antimicrobial coating inhospitable to >99.99% of surface microorganisms. A pilot study on the efficacy testing for use in military operational environments was published in *Military Medicine* in April 2018 [32]. In the studies, MicrobeCare XLP prevented the growth of A. baumannii but had unpredictable results in suppressing S. aureus. This study was funded by the U.S. Air Force Clinical Investigator Program, and the laboratory evaluation was conducted at the 59th Clinical Research Division Laboratory at the 59th Medical Wing at the Joint Base San Antonio-Lackland, TX [32].

MicrobeCare XLP claims to be effective in treating a wide range of products, materials, and surfaces throughout the health care, furnishings, textiles, and commercial industries. The patented technology is peer reviewed and shown effective at protecting products, equipment, and surfaces from microbial contamination while increasing the lifespan, overall durability, and market value of products by inhibiting odors and stains caused by bacteria, mold, and mildew. MicrobeCare is based out of Buffalo Grove, IL [33].

2.2.13 Other

These next technologies could potentially be of interest, though they are geared more toward textile coatings/interactive technologies or are not currently available in the United States.

2.2.13.1 Kastus Surface Coating

Kastus is an Irish surface-coating technology company that produces “always on” antimicrobial protection for glass and ceramic surfaces on smartphones, autoclaves, and touchscreen kiosks. The coating is sprayed onto a surface and sintered into it by high-temperature baking to form a hard surface layer that can kill 99.99% of harmful bacteria and superbugs such as E. coli, clostridium difficile (C. diff.), and MRSA. The focus is to protect consumer electronics and hand-held devices [34]. The surface coating is designed to last the lifetime of the product [35].

2.2.13.2 Mica Nanotech Textilise

Mica NanoTech is a Limerick-based company that has developed a product (Textilise) to coat textiles used in healthcare, such as dressings and gowns to kill persistent bugs like MRSA, E. coli, and C. diff. Cofounder Dr. Patrick Cronin sees disposable, single-use facemasks as another product that could benefit from the novel antimicrobial coating so that they could be reused [14, 15]. The technology is silver-free, endures for greater than 100 wash cycles, and boasts a 100% reduction after 1 hour of exposure. Textilise can be applied to various woven and nonwoven textiles, including polyester/cotton, Kevlar, Nomex, and polyethylene terephthalate

(PET). The mechanism of attachment of the active element to the textile surface ensures excellent durability, ensuring >99% effectiveness against target microbial strain [36].

2.2.13.3 Liquid Guard

Liquid Guard, through a wet wipe application, forms an ultra-thin layer of glass that protects a surface and delivers a safe, modified silica, permanent antimicrobial coating. The nonmigratory coating is antibacterial (including multiresistant bacteria), antiviral (active against transmissible gastroenteritis virus [TGEV] – a model virus for SARS-CoV), and fungicidal, defends against mites, and prevents mold growth. Its applications include aircraft, hospitals, technology, household, sanitary, gastronomy, medicine, public, and agriculture. The Germany-based company has multiple branches across Europe and one in Mexico, but the product is not currently available in the United States or Canada [37].

2.2.13.4 HF Servis and Wero Water Service

HF Servis and Wero Water Service are teaming up for a small-scale program to coat public transportation bus interiors in long-lasting disinfectant (21 days and more) in Prague, Czech Republic. One company (HV Servis) uses a thin layer of Impaguard GCA based on ethyl acetate. The other uses PolyHMG based on the cationic polyhexamethylene guanidine polymer manufactured by Wero Water Service.

Both new formulations have been tested for effectiveness for 21 days. They are broad-spectrum, killing bacterial pathogens such as Escheria coli, salmonella typhimurium, stapylococcus aureus, streptococcus pyogenes, tuberculosis bacteria, yeasts, fungi, and, in the case of PolyHMG, viruses.

They are nonflammable, stable, colorless, and fragrance free. They do not endanger human or animal health or safety, irritate eyes, or mucous membranes or cause allergies. They work in low (up to 0 °C) or high (up to 100 °C) temperatures, do not damage materials, are not corrosive, and do not contain alcohol or aldehydes or phenols. Lastly, they are biodegradable.

All interior surfaces must be thoroughly degreased, ideally twice, before applying the nanopolymer layer. The antibacterial and antiviral agent is then applied in two layers with a spray gun and spread across the surface with a sponge in a cross-wise manner so that no space is left untreated. The polymerization takes about half an hour. The average yield of one liter of the product is 60 to 75 m^2 [38].

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