A DEMONSTRATED LAYER OF PROTECTION

A REVIEW OF ANTIMICROBIAL SURFACE PROTECTANTS

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C&W SERVICES

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Chief Operating Officer

C&W Services is pleased to release our review of antimicrobial surface protectants (ASPs). This is the first in a series of reviews focused on better understanding the variety of products now in the marketplace available to mitigate infection risk. Our subject matter experts working in partnership with the external expertise of Andrew Havics, CIH, have produced a thorough and leading-edge review of understanding products aimed at protecting against infection by the novel Coronavirus, COVID-19.

Our review consisted of selecting manufacturers of ASPs who have provided public review of their lab tests, lab studies, field studies and peer reviews. Each of the 15 products we reviewed was evaluated for efficacy, applicability and potential drawbacks. Our review is based on our first-hand experience with these products together with information supplied directly from the product manufacturers and summaries of third-party lab tests and studies. We believe this kind of clear-eyed analysis has been missing from the industry and as a leader in the field, we saw it as our responsibility to fill that void to improve end-user understanding of various applications.

This analysis and collaboration are consistent with our mission to deliver the most effective cleaning solutions to our clients. Our review of ASPs, along with real-time analysis of regulatory directives for PPE, disinfecting products, alternative approaches to maintenance and hygiene protocols are part of our continued effort to stay at the forefront of assisting our clients.

We’re excited to be sharing this information with you, enabling you to make your facilities safer.

ANTIMICROBIAL SURFACE PROTECTANTS (ASP)

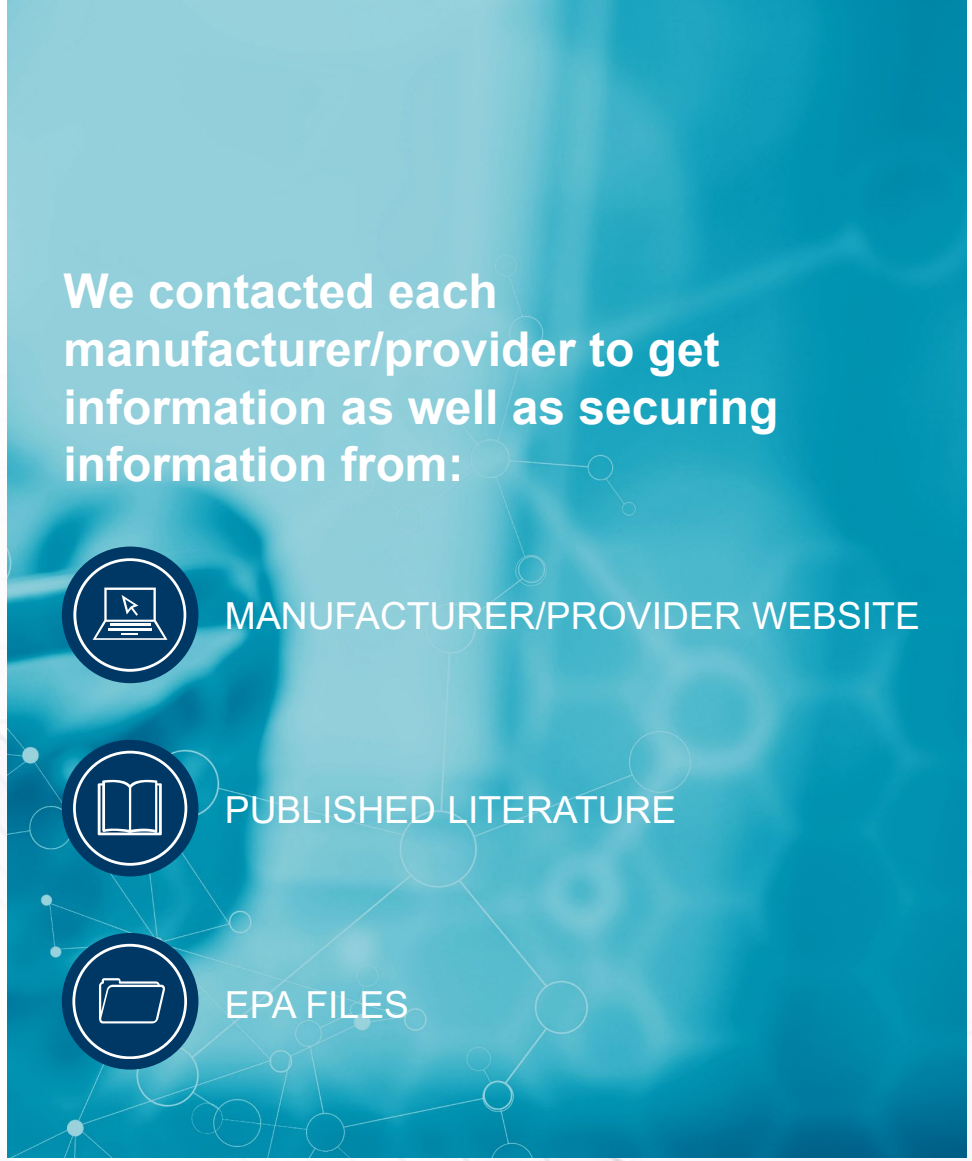
Antimicrobial Surface Protectants are materials that are placed on substrates to prevent microbial growth (bacteria, fungi, algae, viruses, etc.). They may be liquids or a solid film applied (adhered) to a substrate. In the case of a liquid, these may be more like a spray or more like a paint. Liquid application could include brushing, dipping, padding soaking, spraying or using foam finishing techniques. In the case of spraying, this may include a pump spray, carpet/upholstery steamers, rotary jet extraction cleaners, electrostatic sprayers, or pressure sprayers. Each product must be applied following the EPA registration label, if EPA registered. All methods may not be available for application. For instance, Pro-Techs™ should only be applied by an Electrostatic Sprayer. And for the solid films, whether they're in prefabricated shapes or simple flat sheets, they must always be adhered to a substrate.

The categorization is based on the type of product, film or liquid. In terms of extended use of Antimicrobial Surface Protectants (ASPs) [use beyond one day], they, in general, fall into three time periods: 30 days, >30-90 days, and greater than 90 days.

OUR METHODOLOGY: DATA COLLECTION ON ANTIMICROBIAL SURFACE PROTECTANTS

In partnership with a certified industrial hygienist, data was collected on antimicrobial surface protectant products in order to assist in our review. The data we reviewed included manufacturer published or supplied product information and specs, third-party published literature and specific information filed for EPA registration. In some cases, we spoke with CEOs, COOs, chemists, patent holders, sales representatives, and/or technical support personnel. We have collected documentation to support the information provided in this report.

Read more on the EPA's Antimicrobial Testing Methods



ANDREW HAVICS, CIH, PE; PRINCIPLE, PH2 AND PUBLISHED EXPERT

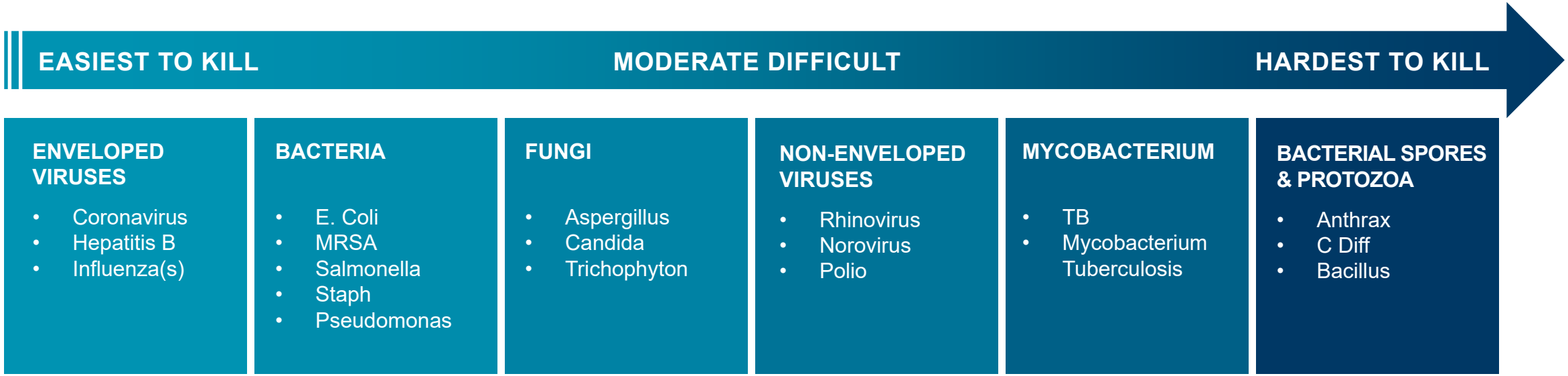
Andrew is a Certified Industrial Hygienist (CIH) and a registered Professional Engineer (PE) with over 30 years of experience in environmental, health and safety, building science and materials science consulting. He is a lecturer at Purdue University and has taught at both IU School of Medicine and IUPUI in Indianapolis.

He has a broad background in analytical techniques from mechanical and physical testing to chemical testing using classical instrumentation with a heavy focus on microscopy. He has performed failure analysis on a variety of materials, including metal and polymer piping as well as tanks, ceramics, brick, stone, concrete, roofing, glass, plastics and electronics.

As a leader in the field, he has been sought out to perform indoor air quality (IAQ) studies for a wide range of facilities, including schools, apartments, colleges, medical centers, and office complexes. He’s also produced plans, specifications and provided oversight for infection control and mold remediation in hospitals, office complexes, banks, schools and residences.

He is a former chair, as well as a current member, of the Workplace Environmental Exposure Limit (WEEL) Committee, which has set over 100 exposure limits for hazardous agents. He’s also a member of the ASTM E50 Environmental, E34 Health Safety, E30 Forensic and E56 Nanotechnology Committees.

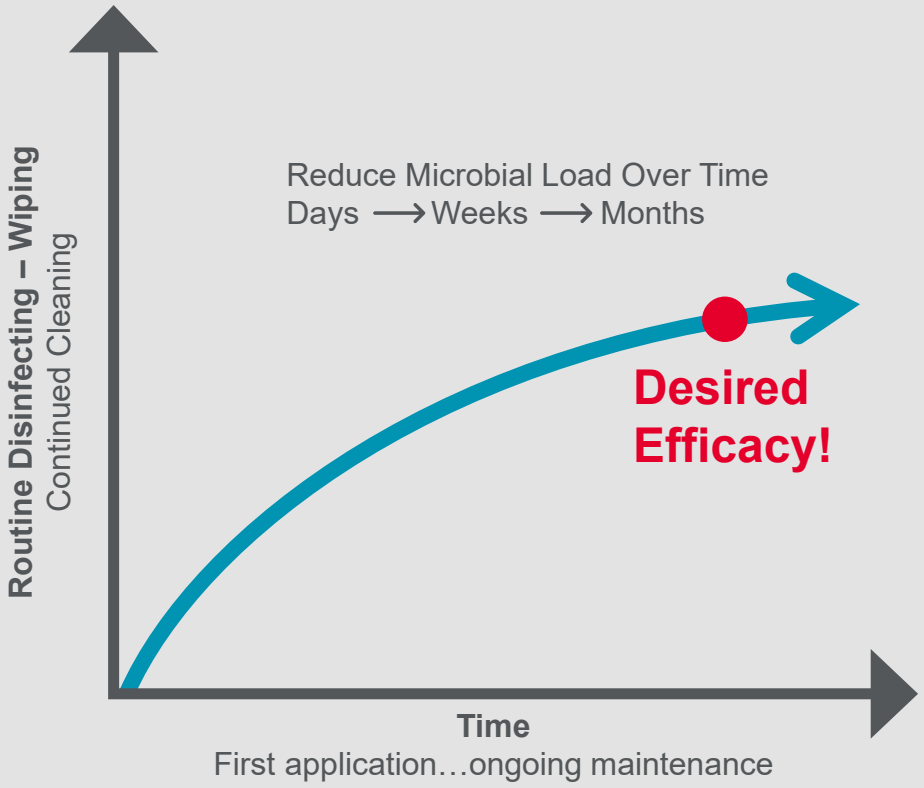
CLASSES OF MICROORGANISMS ACCORDING TO SUSCEPTIBILITY TO DISINFECTANTS



Surface Protectant, Why?

EPA says, “emerging infectious diseases/pathogens” as those “that have newly appeared in a population or have existed but are rapidly increasing in incidence or geographic range.” A prime example is SARS-CoV-2 (COVID-19) which falls in the *enveloped virus* category.

UNDERSTANDING THE USE OF ANTIMICROBIAL SURFACE PROTECTANTS



- Whether chemical or mechanical, the product needs direct contact with the organism in order to work, i.e. < 10 UM (1/10th of a human hair)
- Many of these products are generally designed to reduce microbial load over time by preventing biofilm buildup.
- Reductions in microbial loading tend to be far less than disinfectants
  - Disinfectant provides 3-6 log10 reduction
  - Self-cleaning surface protectants in general < 1 log10 reduction

BACKGROUND

While it is widely admitted that bacteria react to the surface topography, the mechanisms regulating the bacterial response on microscale surface features have not yet been elucidated Ploux, 2010]. A number of studies have tried to elucidate the mechanism [Peng, 2009; Anselme, 2010; Decker, 2014; Decker, 2013; Feinberg, 2008, Myan, 2013; Schumacher, 2007; Xue, 2015]. Our review suggests that these function primarily by limiting the transfer of microorganism to the surface, secondarily by limiting adhesion to the surface, and tertiarily by creating stress on the cell wall through bending or uneven surfaces.

Other Agents Similar to Organosilane

In addition to organosilane Quats, there are a couple of other organics that are functionally similar. These include polyhexamethylene biguanide (PHMB) and hydrophobic NalkylPEI (where PEI stands for branched 750kDa polyethylenimine) polycations [Hedin, 2010; Haldar, 2007; Kugel, 2011; Park, 2006]. Polyaminobiguanide is a similar compound (same biguanide molecule on a chain) that is found in both MyShield7 and Disinfect and ShieldTM. However, it is not claimed as the active ingredient in these products.

Other organics have been considered for coatings, such as bacteriolytic enzymes, coatings based on essential oils, and coatings based on antimicrobial peptides [Glinel, 2012]. None of these were evaluated.

BACKGROUND

SPECIFIC TYPES OF ASPS

Several types of ASPs are functionally active by chemical and some by physical methods. In some respects, they overlap. These may be grouped as Organosilane Quats (Si-Quats), Organometallics, Elemental Metals, Photocatalytic Oxidizing (PCO) Agents, Physically Structured Preventatives, and Other Organosilane-like Agents.

Organosilane Quats (Si-Quats)
These materials are contact kill coatings. Contact active antibacterial agents refer to those biocides that inactivate bacteria on contact while being bound on surfaces. The most commonly reported contact active antibacterial agents include quaternary ammonium compounds (QACs) such as alkyl pyridiniums and quaternized poly(2 (dimethylamino) ethyl methacrylate), quaternary phosphoniums (Qps), and Monochloramines [Kaur, 2016].

In the mid-1960s, researchers discovered that antimicrobial organofunctional silanes could be chemically bound to receptive substrates by what were believed to be SiO linkages. The method was described as orienting the organofunctional silane in such a way that hydrolysable groups on the silicon atom were hydrolyzed to silanol and the silanol formed chemical bonds with each other and the substrate. The resultant surface modification, when an antimicrobial moiety such as quaternary nitrogen was included, provided for the antimicrobial to be oriented away from the surface.

The antimicrobial activity of solid surfaces treated with the SiQuat agent was first described by Isquith in 1972 [Isquith, 1972]. The antimicrobial activity of the [3(trimethoxysilyl) propyldimethyloctadecyl] ammonium chloride (SiQuat) has been studied extensively on a variety of treated surfaces [Monticello, 2010] and is the main component of many of these products. ASPs with this as their active ingredient are MicroShield360™, Bioshield7, Surfacewise2™, Disinfect and Shield™, Micoban7 Microshield and Excalibur, Bioprotect™, PreventX 24/7™, and MyShield7.

Si-Quats has been shown as a group to be effective against bacteria, fungi, algae, and viruses [Monticello, 2010; Weber, 2019; Boyce, 2016]. Functionally, three methods have been proposed for the actual killing effect: polymeric spacing effect (marketed as a micro sword), an ion-exchange mechanism, and phospholipid sponge effect [Kaur, 2016]. None of these methods are able to successfully explain experimental effects and thus there is likely a combination of mechanisms, the most supportive having to do with electric charge.

Because each Si-Quat blend can be different organosilane support and have different amounts of active agent, the ability to reduce microbial growth will vary based on the product. Some products have more data or better quality data for their particular product. In general, they are relatively successful at reducing microbial bioload.

BACKGROUND

Metal Ions
In general, the primary metal ions used as antimicrobials are copper, silver, although gold, zinc, and others have efficacy.

Silver has been used extensively throughout recorded history for a variety of medical purposes. Silver ions have the highest level of antimicrobial activity of all the heavy metals [Weber, 2019]. Although many mechanisms for silver=s bactericidal activity have been proposed, the observed bactericidal efficacy of silver is thought to be through the strong binding with disulfide (SS) and sulfhydryl (SH) groups found in the proteins of microbial cell walls. Through this binding event, normal metabolic processes are disrupted, leading to cell death [Weber, 2019].

Copper has been used for centuries as a medicinal and to prevent the growth of barnacles on the hulls of ships [Grass, 2011; Elguindi, 2001] However, copper ions at increased levels are toxic to most microorganisms because of their ability to generate reactive oxygen species and act as a strong soft metal (e.g., leading to release of iron from FeS clusters) [Elguindi, 2011; Samanovic, 2012]. The copper generated radicals can damage lipids, nucleic acids, and proteins, leading to cell death. In health care, copper compounds (i.e., copper/silver ionization) are used for control of Legionella species in water supplies [Lin, 2011] and Aspergillus on building materials (i.e., copper8quinolinolate) [Weber, 2009]. More recently, copper-coated or impregnated surfaces have been evaluated in hospitals successfully [Elguindi, 2011; Samanovic, 2012; O=Gorman, 2012].

Photocatalytic Oxidizing (PCO) Agents
PCOs are typically titanium dioxide light-activated photosensitizers, such as nanosized titanium dioxide (TiO2) applied to surfaces with UVA or visible light to generate reactive oxygen species that can disinfect surfaces [Boyce, 2016; Humphreys, 2014; Pulliam, 2015; Kim, 2018; Ditta, 2008]. Titanium dioxide compounds doped with other metals (e.g., Silver [Ag], Zinc [Zn], Copper [Cu]) have been assessed for antimicrobial activity. Such compounds have demonstrated the inactivation of pathogens (i.e., viruses, bacteria, and fungi) associated with HAIs. However, the rate of decrease depends on thin film composition and the illumination used [Villapun, 2016; Querido, 2019]. There are historical issues with PCOs and the second-generation products are more apt to work in the lab-based on over 150 studies [Demirel, 2018]. Results from PCO in the hospital environments are mixed in terms of both microorganism growth and HAIs [de Jong, 2018; Pulliam, 2015; Kim, 2018; Chung, 2008].

Physically Structured Preventatives
Through bioinspired research, it has been found that certain micro-structured surfaces inhibit microbial adhesion and growth [Decker, 2014; Decker, 2014; Feinberg, 2008; Mann, 2014; Myan, 2013; May 2011; Schmid, 2011; Schumacher, 2007; Peng, 2009; Nihiser, 2014]. This includes one product reviewed, Sharklet™.

ASP CRITERIA FOR EVALUATION:

C&W Services stands prepared to help you analyze which ASPs may be most suitable for your particular environment. Below are the minimum criteria your business should consider to best determine which ASPs will meet your specific needs.

Product Data

- Is it EPA Registered?
  - For what organism
  - Label restrictions
- Manufacturer's Warranty?
  - Time, limitations

Usage

- Surface application possibilities
  - Ceiling, walls, floors, tables, chairs, knobs, doors, etc.
  - HVAC coils & drip pan
  - Duct interior
  - Gymnastics/Wrestling mats, weight lifting equipment
  - Rock climbing walls
  - Buses, Trucks, cars/taxis
- Where is it applicable to use specific substrates? Substrate restrictions?
  - Wood, textile, metal, drywall, plaster, paper, SS, brick, etc.
  - Preconstruction application or installation
  - Uniforms
- Cleanability?
- Color restrictions?
- Requirement for Manufacturer's approved installers/appliers?
- Application Mechanism
  - Spray coat, mist, wipe, roll, on lay, install, etc.
- Interior/Exterior
- Frequency/Length of application (hours, days, weeks)
- Removability & disposition upon end of use

Efficacy

- Theory Behind mechanism
  - Assumptions & Limitations
  - Published description
- Patent Claim
  - Published Lab data to support
  - Unpublished Lab data to support
  - Published Field data of Organisms to support
  - Unpublished Field data of Organisms to support
  - Published Field data on Acquired Infection Rate to support
  - Unpublished Field data on Acquired Infection Rate to support
  - Overall Weight of science to support
- Which organisms
- Decrease rate

Health & Safety

- Exposure to any agents for those installing/applying
- RfD, RfC
- Sensitizer?
- PPE required
- Ventilation required
- Leaching?

Material Properties

- Acoustics (Sound Absorption Coefficients; Transmission Coefficient)*
  - RValue, if on exterior Wall
  - Water Vapor Permeability, if on exterior Wall
  - ASTM E 84 Flame Spread
  - ASTM E 84 Smoke Developed Index
  - ASTM E1678 Toxicity Evaluation of Smoke Produced
  - Heat Aging Without Load, if > 1 year
  - Wear resistance (if on floor, high contact surface, if > 1 year...)

BASED ON THE CURRENT NEEDS OF C&W SERVICES AND OUR CLIENTS AND CUSTOMERS, CRITICALLY RELEVANT CRITERIA WERE REDUCED TO THE FOLLOWING FOR OUR REVIEW:

EPA Registration
We reviewed the ASPs to determine if they had EPA registration, had applied for EPA registration or had no EPA registration. Values of 5, 3, and 0 were applied to each, respectively.

METP
The Maximum Effective Time Period (METP) was based on efficacy by lab or field data. The quality of efficacy (% or Log10 reduction) was not considered in this criterion but was considered in other criteria.

Immediate (Short-Term) Reduction in Microbial Activity
We reviewed the quality of efficacy (Log10 reduction) based on the most representative lab data available from tests of 1 to 24 hours in length. We do not consider a particular organism as more or less important than another.

Long-Term (Chronic) Reduction in Microbial Activity
We evaluated the quality of efficacy (% or Log10 reduction) based on the most representative field data available from data over 2 weeks in length. We do not consider a particular organism as more or less important to another. We also considered indirect surrogates, e.g., ATP, the same as a specific microorganism.

Testing on Viruses
We evaluated whether there was in-lab testing of viruses for the product. A product may have been tested against SARS-CoV-2 (COVID 19), other human coronaviruses (e.g., HcoV 229E), feline viruses, etc.

INDUSTRY EXPERT, ANDREW HAVICS, CIH, PE, ANALYZED THE FOLLOWING CRITERIA FURTHER:

Lab Data to Support Surface Efficacy
Completed an evaluation of the surface (applied product) efficacy from lab testing. This was followed by testing like-for-like product samples with the same active ingredients.

Field Data to Support Surface Efficacy
Completed an evaluation of the surface (applied product) efficacy from field testing. This was followed by testing like-for-like product samples with the same active ingredients.

Healthcare Acquired Infections (HAIs)
We reviewed the surface (applied product) efficacy from field testing for HAIs base on the weight of the number of studies available (published and unpublished combined).

Application of Films
We reviewed solid films separately because certain aspects of application were more relevant for these products than for the liquids. This included transparency, application ease and adherence, and the ability to provide a pre-shaped product.

Application of Liquids
We reviewed liquids separate from solids as discussed above. We considered whether there were significant PPE and training required for application, whether the product had only one application means (for example, Electrostatic spray only), and whether there were limitations to the surface that it might be applied to.

Limitations
We were unsuccessful in getting data in certain aspects due to confidentiality or lack of response by the company. We have evaluated the products based only on what we were able to acquire and verify in writing. Some of the data we acquired is confidential. We have summarized certain aspects to maintain confidentiality.

EVALUATION CRITERIA TO DETERMINE EFFICACY AND RISK MITIGATION

LOW VALUE → HIGH VALUE

Criteria	Criteria Measure or Class Distinction						
EPA Registered		None	None	None	Pending		Yes
Effective Time*	With Data to Support	< 1 Hour	1 -24 Hours	> 1 -7 Days	> 7 – 30 Days	> 30 – 90 Days	> 90 Days
Immediate (short-term) reduction	Bio Load (Log 10)	< 1	1+	2+	3+	4+	5+
Long-term reduction (2 Weeks +)	Bio Load (Max)	No Data	20%	40%	60%	1+	2+
Testing on Viruses	Lab or Field	0	Similar Class of Product**	Product Same Active Ingredient	Coronavirus for Same Class Product	Coronavirus for Product Same Active Ingredient	Coronavirus for Product
Lab Support	Surface Efficacy Reports	0	1+ for Similar class of product	1- 3 for product same active ingredient	> 3 for product same active ingredient	1- 3	> 3
Field Studies	Surface Efficacy Reports	0	1+ for Similar class of product	1- 3 for product same active ingredient	> 3 for product same active ingredient	1- 3	> 3
Healthcare Acquired Infections (HAIs)	Peer Review Studies	0	1+ for Similar class of product	1- 3 for product same active ingredient	> 3 for product same active ingredient	1- 3	> 3
Application	Film	Non-Transparent, Difficult to Apply	Transparent; Difficult to Apply	Non-Transparent; Prefabricated for Odd Surfaces	Transparent; Easy Adherence to Smooth Surfaces or Non-transparent over uneven surfaces	Transparent; Prefabricated for Odd Surfaces	Transparent Over Uneven Surfaces
Application	Liquid	Significant Constraints (Surfaces limited; Capital + PPE + Training	Single method; Significant Capital Investment + PPE	Single method; Significant Training or Significant Capital Expenses	Single Method; Little to no training or Multiple Methods; Significant Capital Expenses	Multiple Methods; Significant Training	Multiple Methods; Little to no Training
Technical Support Expertise	History and Personnel	< 1 Year; No Expert Available	> 1 Year; No Expert Available	> 1 Year, Chemistry Expert Available	> 5 Years, Patent Expert Available	> 10 Years, Patent Expert Available	> 20 Years, Patent Expert Available

**Presumes some level of surface cleanliness to work*
***Class and agent type (e.g. Organosilane to organosilane + quat to quat, metal to metal*

KEY SUMMARY OF OUR ANTIMICROBIAL SURFACE PROTECTANT REVIEW

- ASPs have shown to be effective in reducing HAIs and '*Surface to Human'* cross-contamination in healthcare environments. With proper maintenance and application, these products can provide a level of assurance not typically seen in non-healthcare settings.
- Just as each environment is unique, each ASP should be reviewed for its applicability to each environment. In reviewing our own diverse portfolio, C&W Services was able to recommend a product match in almost every instance – commercial, retail, transportation, manufacturing, GMP, food production, education, and general office space.
- Each product in this class has its own unique characteristics. Understanding the applicability, the environment and potential strengths and weaknesses of each ASP can assist in improving efficacy.
- With the proper equipment, training and maintenance, this product class and each category (liquid, film or paint) can provide an additional layer of protection against viruses like COVID-19 and influenza for periods of 30 to 90 days for liquid and film ASPs and for much longer periods of time for ASP treated paints.
- Liquid ASPs are the most diverse in this product category. In most cases, they offer the most coverage when applied with an electrostatic sprayer. Liquids can be applied to both hard surfaces and most fabrics without issue. All liquids are susceptible to abrasives and caustic chemicals (Ph greater than 11.5 – alkaline). Excessive traffic or highly-dense space may necessitate more frequent reapplication, and excessive dust may undermine efficacy.
- Films should only be applied to touchpoints such as door handles, handrails, and elevator buttons. Certain manufactures can create custom-cut films for unique or uneven surfaces. As with liquid ASPs, excess dust can undermine the films efficacy.

None of the products are guaranteed to eliminate all exposure vectors and should be used in conjunction with good hygiene practices and CDC guidance

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