Applied Silver
Commentary

A Mechanistic Comparison of Residual Antimicrobial Additives For Laundry

SilvaClean® (ionic silver) vs. Quaternary Ammonium Compounds

Introduction

Antimicrobials, in the form of antibiotics, antiseptics and disinfectants, may be among the most influential inventions in modern medicine for treating and preventing infection. The "antibiotic era" began in early 1900s with the introduction of antibiotics used for treatment of patient infection and in some cases prophylaxis (1). Non-antibiotic antimicrobials (antiseptics, disinfectants and others) have been in use much longer, in some cases for centuries, to prevent the growth and transmission of microorganisms and communicable diseases. The use of these products is in two primary areas; 1) disinfectants for the environment (i.e. hard and soft surfaces) and 2) antiseptics for the body (e.g. surgical skin preparation solutions, antimicrobial soap). This technical report discusses examples of antimicrobials specifically used in industrial laundry applications as immediate (quaternary ammonium compounds (QACs, or quats) and residual antimicrobial additives (SilvaClean's ionic silver).

Antimicrobials in laundry applications

Textiles represent a large surface area in our daily lives. In hospitals, healthcare textiles represent a surface that is most in contact with the patient's skin, and one that is transported in and out of patient facilities and hospitals, including to the site of laundry reprocessing. Healthcare textiles that are returned for re-laundering can often arrive heavily contaminated with infective body fluids as well as shed skin - as much as 1×10^4 to 1×10^6 colony-forming units of bacteria per square centimeter of fabric (2). Similarly, athletic soft surfaces such as dirty uniforms and towels pose a risk to players and teams within sports facilities (3). While commercial and on-premise laundries follow standard operating procedures to provide hygienically clean textiles to their users (4), the "clean" textiles can have some, albeit low levels of microorganisms.

New innovations in residual laundry-based antimicrobials address a unique gap in the laundry cycle: contamination that occurs in use or in storage of the laundered items.

Silver ions and QACS both exhibit enhanced antimicrobial properties making them highly applicable in the industrial laundry industry as the antimicrobial partner to laundry detergent which removes dirt, stains and soil. In this summary, we will look at the features and benefits of each when used as laundry additives.

SilvaClean Ionic Silver Application

SilvaClean residual antimicrobial laundry additive is based on the ancient antimicrobial chemistry of silver in its ionic form. The antimicrobial properties of silver have been known for centuries. Silver was originally discovered for its antimicrobial properties in the 4^{th} century by the father of modern medicine, Hippocrates (5). Silver has been used throughout the course of history, from ancient civilization (i.e. Romans, Phoenicians and Greeks). In the 19^{th} and 20^{th} century, common medical tools like sutures and gauze made of silver were used for their antimicrobial capabilities.

Silver is #47 on the periodic table of elements. It is a transition metal located in "Group 11," the 11^{th} vertical column on the periodic table between copper and gold in which it shares many of its metallic properties; low electric resistivity and high antimicrobial capability.

A silver ion is formed when atomic silver loses one electron (Figure 1). Silver in its metallic (Ag^0) state is not reactive whereas ionic silver (Ag^+) is highly reactive towards microorganisms; it interacts with and disrupts microorganisms by bonding to negative charges on their surfaces and internal proteins.

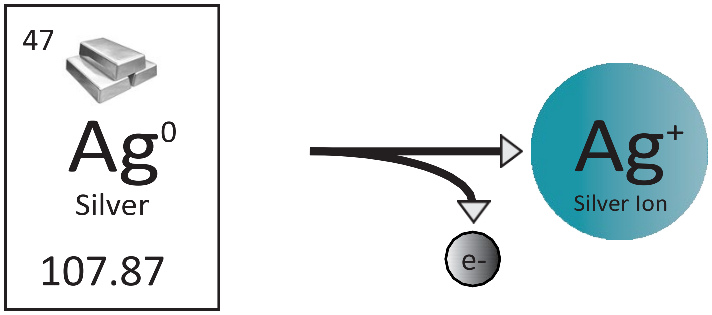

Figure 1: The mechanism in which metallic silver oxidizes to the silver ion: when a metallic silver atom with neutral charge, Ag(0), is oxidized by a reducing agent, it converts to an positively charged ion in the form of Ag(+).

Today silver is used in many forms. Metallic silver, for example, is often threaded into knits, weaves and meshes to enhance fabrics with antimicrobial properties. Silver may also be used in a liquid form as a silver salt. The liquid form contains silver ions in their active state, where the metallic silver thread must be oxidized (usually with water or air) to transition to the active ionic silver state. Once in ionic state, silver binds to textiles via a charge-charge interaction, effectively providing a residual effect.

The reason that silver has been continuously used over the years is because of its natural ability to kill harmful microorganisms like bacteria, fungi and viruses. Unlike other antimicrobials, silver has not one, but three mechanisms of action (6, 7). There is a limited set of studies that show resistance development from bacteria towards silver (8-10).

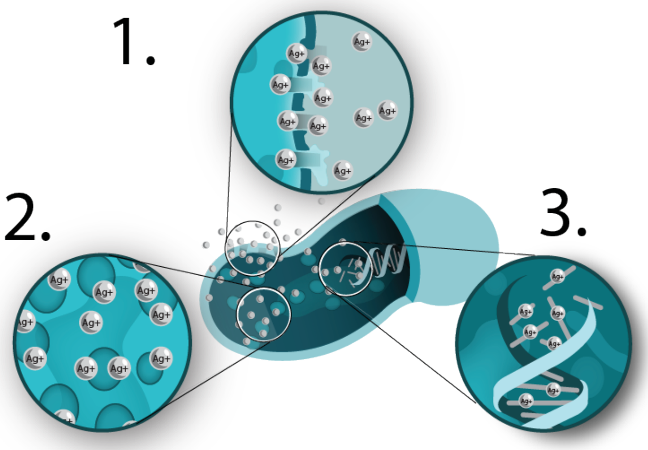

Figure 2: The three antimicrobial mechanisms of silver ions, as displayed on a bacterial cell cutout.

Silver ions are reactive to bacteria in both wet and dry conditions; no moisture is required for silver ions to exhibit an effect on bacteria. In dry storage applications, a silver ion fabric treatment can be used to preserve and protect fabrics due to the sustained antimicrobial effect. It has been reported that hospital patient fabrics (bedding and gowns) treated with ionic silver contain fewer counts of bacteria in these storage rooms when compared to regularly laundered fabric (11). In a laundry application, silver ions can be used in a variety of water types and can be dose adjusted as needed for hard water, high chloride content, etc. Rather than use as a "cleaner," silver ions can be added to laundry processes as a supplement to typical chemicals to residually kill pathogens following laundering while fabrics are stored or used.

Silver's wide applications and ability to be effective in a variety of environmental situations is largely attributed to its three-pronged antimicrobial mechanism (Figure 2).

Quaternary Ammonium Chlorides (QACs)

QACs were discovered in the early 1900s. QACs are cationic surfactants (wetting agents) that double as antimicrobials. The structure generally consists of an organic cationic nitrogen (N^{+}) bonded to four alkyl groups (R) of carbons with an ionic bod to an anionic halide (X^{-}) that is usually chloride, bromide, iodide or a sulfate ion (Figure 3). The ammonium structure acts as the positive, ionic side of the molecule with the alkyl groups acting as the hydrophobic, fatty-like tails. Because its two sides behave as two different molecules, it can easily interact with a variety of different organic (or oil-based) molecules, like bacteria. QACs bind to and destroy bacterial cell membranes when the alkyl groups interact with the lipid bilayer on a cell membrane, releasing the inner contents of the cell.

QACs are well known for their germicidal properties. They were originally used to decrease surface tension of water and was first observed to exhibit effects against bacteria in the early 1900s. Since then, they have been used in a variety of industrial applications, including water treatment, agriculture, consumer products, preserving agents, foamers, soaps, and detergents.

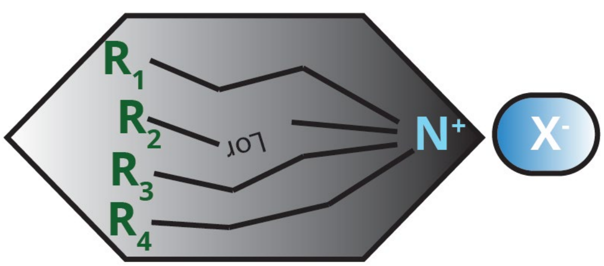

Figure 3: Generic Structure of a Quaternary ammonium chloride. The four alkyl (R_n) groups act as the hydrophobic group while the cationic Nitrogen and Anionic Halide act as the hydrophilic group allowing it to interact with both oil and water.

QACs only interact with bacteria primarily on the cell membrane and cell wall, not with internal components. Because of this, there is widespread resistance to QACs in pathogenic and clinically relevant bacteria (12,13). Bacteria are able to mutate in a way that they alter their membrane structure so that the QACs are unable to interact with the cell layer and therefore are unable to kill the cell.

Another drawback the quaternary ammoniums incur is that they are sensitive to water qualities and parameters (i.e. temperature, hardness, pH, etc.). Industrial water qualities can change significantly in short periods of time due to errors in the industrial process (water boiler turns off, water softener depletes). This creates a risk of rendering QACs used in laundering ineffective, leaving laundry not properly cleaned.

QACs have been used for more than 100 years for their ability to clean surfaces, both soft and hard. While they do have some drawbacks, QACs are still widely used all throughout the healthcare and consumer industry for

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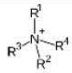
detergents, soaps, etc., and show no signs of being replaced in the near future.

SOLUTION ATTRIBUTES	***BacStat Quats***	***SilvaClean residual antimicrobial laundry additive***
Active Ingredient	Quaternary ammoniums	Silver ions
Symbol		Ag+
Required conditions for effectiveness	**Wet:** BacStats kill microbes only under fully wet conditions, and are inactive when textile is dry	**Wet or Dry:** SilvaClean kills microbes anytime they land on the textile, providing a continuous killing action
Antimicrobial mode of action	**Bacteriostatic**: Incomplete kill. Microbes can recover and grow.	**Bactericidal**: Complete kill. Microbes do not recover and grow.
Mechanisms of antimicrobial activity	**Cell lysis:** Disrupt cell membrane while in a common liquid solution	**Oligodynamic:** 1) Punctures cell membrane, 2) Deactivates metabolic enzymes (suffocation) and 3) Prevents DNA replication
Presence on fabric	Residue	Residual Chemical Bond
Required laundry soak time	5-8 mins	< 2 mins
Use Case	**Narrow:** Incontinence pads, spills	**Broad:** All healthcare textiles: in transportation, storage and during use
Skin Sensitivity	Known to irritate and or dissolve patient skin.	None. Safe to use even in pediatric wards.
EPA Public Health Claims	**No.** Claims limited to inhibition of stain and odor causing bacteria, mold and mildew.	**Yes.** 99.9% kill of key pathogens including antibiotic resistant microbes and yeast. Product also inhibits stain and odor causing bacteria, mold and mildew.

QACs and silver have been reported to be complementary in their combined antimicrobial efficacy (14-16). QACs, however, have several more drawbacks when compared to silver ions when used on their own (see Table). For example, quaternary ammonium compounds require conditions of high relative humidity (17), have a limited mechanism of action, and require a minimum rinse time (i.e. 8 minutes) to work properly. SilvaClean's silver ions, on the other hand, can be applied by an automated IoT smart-dispensing system, act in three ways, and utilize the existing processes at a laundry plant (no extended rinse times). In addition, silver ions have a multi-year shelf life and work in wet or dry conditions.

Conclusion

Silver and QACs both have numerous benefits when used as antimicrobials. Silver is proficient at residually killing post-laundry pathogenic contamination while fabrics are stored and used. QACs are proficient in cleaning dirt, grime, and soil that might contain harmful microbes, but fail to perform in dry conditions and when the water quality is not optimal (high mineral content). With the rise of infections globally, inclusion of residual antimicrobials, particularly one that can impart continuous antimicrobial properties under all conditions of storage and use, can prove as an effective infection control tool.

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