The Quat Advantage: Quaternary Ammonium Chloride and Its Advantages in Healthcare Facilities

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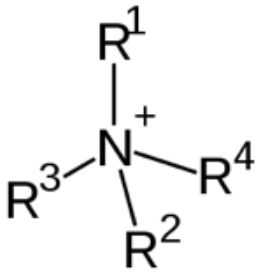
Background

Quaternary ammonium chloride (QAC) compounds are the most common active ingredient found in disinfectants used in healthcare environments. This is largely because products formulated with QACs are readily available and versatile. In addition, the products typically offer broad-spectrum efficacy and do not have the unpleasant odor of oxidizing-based products, such as Sodium Hypochlorite (Bleach) and Hydrogen Peroxide.

The basic chemical structure of QACs consist of a nitrogen atom with some combination of four other organic chains or rings as shown in Figure 1.

Figure 1. Quaternary Ammonium cation



The QAC market has substantially evolved since its inception more than 100 years ago and has significantly matured providing disinfectant solutions that today provide improved benefits compared to historical QAC disinfectants. Due to the limitless number of possible combinations, there are many different versions of QACs on the market already and new ones are constantly being developed. The most current QACs on the market are seventh generation providing enhancements in efficacy with less toxicity. Table 1 outlines the evolution of QACs.[1]

This communication is intended to identify the many benefits of QAC's and provide insight into the future of QAC's for use as active microbial agents in surface disinfection products.

Table 1. Outline of the various generations of QAC's.

FIRST GENERATION: Benzalkonium chlorides (example: Benzalkonium chloride). First generation QACs have the lowest relative biocidal activity and are commonly used as preservatives.
SECOND GENERATION: Substituted benzalkonium chlorides (example: alkyl dimethyl benzyl ammonium chloride). The substitution of the aromatic ring hydrogen with chlorine, methyl and ethyl groups resulted in this second generation QAC with high biocidal activity.
THIRD GENERATION: "Dual QACs" (example: contain an equal mixture of alkyl dimethyl benzyl ammonium chloride + alkyl dimethyl ethylbenzyl ammonium chloride). This mixture of two specific QACs resulted in a dual QAC offering increased biocidal activity, stronger detergency, and increased safety to the user (relative lower toxicity).
FOURTH GENERATION: "Twin or Dual Chain QACs" – contain dialkylmethyl amines (example: didecyl dimethyl ammonium chloride or dioctyl dimethyl ammonium chloride). Fourth generation QACs are superior in germicidal performance, lower foaming, and have an increased tolerance to protein loads and hard water.
FIFTH GENERATION: Mixtures of fourth generation QACs with second-generation QACs (example: didecyl dimethyl ammonium chloride + alkyl dimethyl benzyl ammonium chloride). Fifth generation QACs have outstanding germicidal performance, are active under more hostile conditions and are safer to use
SIXTH GENERATION: Polymeric Quaternary Ammonium Chlorides
SEVENTH GENERATION: Bis-Quaternary Ammonium Chlorides with Polymeric Quaternary Ammonium Chlorides

QAC Activity

QACs are good cleaning agents and are widely used as disinfectants for noncritical environmental surfaces in healthcare settings. QACs have the broadest spectrum of any microbial agent, having shown efficacy against Bacteria, Viruses, Protozoa, Fungus, and Algae commonly found in healthcare environments. The broad spectrum efficacy claims obtained from the QAC along with the ability to couple with alcohol allows for a broad spectrum disinfectant with a fast contact time (less than or equal to 3 minutes) and excellent compatibility. The bactericidal action of the QACs have also been attributed to the inactivation of energy-producing enzymes, denaturation of essential cell proteins, and disruption of the cell membrane.[2]

Generalized statements that QACs overall are not effective against target organisms has led to a misrepresentation of the efficacious ability of QACs to mitigate specific target organisms, specifically Norovirus. QAC-based formulations are tested using the Environmental Protection Agency (EPA) standardized testing protocols for claims against a specific organism. These tests must be conducted with the specific organism to ensure efficacy. In numerous studies published, the authors neglected to determine if the product had been registered for that specific organism or application, and most of the QACs had been tested alone versus in conjunction with many of its synergistic partners.[3] In fact, QACs alone have the ability to mitigate 37 of the top 50 organisms as well as persistent organisms, such as Acinetobacter spp (3 days to 5 months), Chlamydia psittaci (15 days), Shigella spp (2 days to 5 months), MRSA (7 days to 7 months), Adenovirus (7 days to 3 months) and Candida Albicans (1-120 days).[4]

Compatibility

One of the advantages of Quaternary ammonium disinfectants is that they do not damage clothing and carpets the way that oxidizing chemistries do. They are also non-corrosive to metal pipes and other surfaces.[5] QAC formulated disinfectant products predominantly sold into the healthcare surface disinfectant industry are diluted for easy use, and therefore possess a much lower risk of damaging surfaces versus concentrated QAC forms. As a results of the formulation properties, QAC-based as well as alcohol/QAC-based disinfectant products provide exceptional material compatibility as shown in table 3. These alcohol/QAC-based formulations are safe for repeated use on hard, non-porous surfaces. With repeated use, these formulations do not streak or build up on the surface.

A study conducted by Lonza in 2002, provided data from a material compatibility test demonstrating the advantage of using QAC-based disinfectants versus Hydrogen Peroxide-based formulation on rolled steel.[7] This value proposition of enhanced material compatibility provided by a QAC-based formulation is seen on most metal, plastic, and fabric material compositions, and these findings have been correlated to over 70% of the medical device manufacturers in the healthcare industry. [8]

Table 2 outlines the advantage of QACs versus various other types of disinfectants.

	QUATERNARY AMMONIUM CHLORIDES	BLEACH	HYDROGEN PEROXIDE	CHLORINE DIOXIDE	PERACETIC ACID
Effective pH	1-13	9-13	1-5	1-14	1-5
Cleaning	Good	Poor	Poor	Poor	Poor
Staining	No	No	Yes	Yes	No
Odor	Low	High	Moderate	High	High
Skin Irritation	Low	High	Medium	High	High
Storage Stability	Excellent	Poor	Poor	Poor	Poor
Disinfection (ppm)	450-850	200-5000	500-1000	5-10	<50
Sanitization (ppm)	150-400	50-200	50-100	<5	5-10

Table 3: Material Compatibility testing conducted by 3rd party comparing Hydrogen Peroxide (3%) with QAC.[6]

	304 SS	ACETAL	BUNA	EPR,EPDM	FLUOROCARBON	FLUOROELASTOMER (FKM)	TPE	NITRILE (TS)	NYLON
H2O2	—	D	B	B	A	A	D	—	D
QAC	A Polychloroprene	— Polypropylene	A PTFE	— PVDF	A Santoprene	A UHMWPE	—	A	—
H2O2	D	A	A	A	A	A			
QAC	A	—	A	—	—	—			

Stability

Not all disinfectant chemistries possess the same stability. The stability property of some chemistries can lead to exothermic decomposition caused by the interaction with other chemicals. In most cases, this can lead to the formation of gases and other bi-products, categorizing these types of chemistries as Reactive Oxygen Species (ROS). This is influenced by a variety of effects ranging from temperature, pH, and the presence of other reactive components. The inability to stabilize these disinfectant formulations properly can lead to challenges in finished product packaging as well as once applied to surfaces. In most instances, oxidative chemistries currently in the surface disinfectant market require two part activation, short product shelf life, and, in some cases, require an additional cleaning step or pre-cleaning.

QAC-based chemistries provide superior stability properties versus any other disinfectant chemistry with having a shelf-life greater than three (3) years. This value proposition of a greater than three (3) year shelf life provided by QACs is not available in any aqueous oxidizing disinfectant formulation. In addition, the active QAC component has been tested to be stable and continue to be efficacious at elevated temperatures at both basic and acidic pH ranges.

QAC Misconceptions

A misconception is that QACs lose effectiveness when mixed with organic matter, such as blood and/or in the presence of hard water. In fact, advances in the area of formulation science allow for surfactants and modifiers to be introduced into the formulation as inerts to provide for improved effectiveness and cleaning performance for blood, urine, and other soil types found on surfaces.

Another important misconception is that continuous use of QAC-based chemistries results in the development of antimicrobial resistance, but recent publications have proved this to be untrue.[9, 10, 11] These recent reviews provide evidence and basic theory based on the mode of attack that QACs utilize that it is highly unlikely it would lead to treatment failure. In addition, a study conducted by Meyers C. in 2010, provided data that rotating different QAC formulations in healthcare reduce the risk or the probabilities that environmental treatment would improve. Research regarding resistance to biocides, specifically QAC-based formulations, has not provided evidence to substantiate this resistance theory. In most instance, the root cause associated with these false positives stem from incorrect handling of product, sample preparation, and human error.[6]

Conclusion

QACs have been extensively studied for their efficacy, safety and toxicity, and environmental effects, and continue to serve as the primary form of surface disinfection in the healthcare environment. QAC-based formulations continue to evolve and provide broad spectrum efficacy, short contact times, extensive shelf life and stability profile, low odor, safety, and a wide effective pH range. The misconceptions regarding QAC-based chemistries in the public have proven to be false and lack the evidence-based data to substantiate the claims. Lastly, QAC-based surface disinfectant formulations provide the advantage of a highly compatible formulation that is non-corrosive on metal surfaces and with the majority of medical grade plastic types having strong material compatibility. The four main pillars to a strong and effective surface disinfectant product, efficacy, contact time, safety and toxicity and compatibility, are what continues to enhance the popularity of QAC-based chemistries and serve as the top infection prevention solution for surface treatment in the healthcare environment.

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