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ICP/MS ANALYSIS of SILVER as an ANTIMICROBIAL AGENT

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The precious metal silver, unlike any other metal, is a natural antimicrobial agent. It is noted that silver is effective against many different bacteria, fungi, and viruses. In fact, early civilizations such as the ancient Phoenicians who flourished around 1200BC, used silver bottles to prevent their drinking water from spoiling. The use of silver for medicinal purposes is actually documented all the way back from 750AD with the first scientific papers published on the subject starting around 1881. The use of silver to prevent infection continued through history into the first World War until the discovery of penicillin in the 1940's. In the 1960's, silver use was revitalized in the form of $AgNO_3$ for burn care management.

Today, with the ever increasing amount of antibiotic-resistant strains of bacteria, the use of silver as an antimicrobial agent has made a resurgence in medicine and also maintains a great deal of relevance to many fields of study and industries. Because of its favorable chemical properties, natural abundance, simple and effective mechanism of action, minimal bacterial resistance, and low toxicity, silver is currently being integrated into many different applications. Today, one will find silver widely used in water filters, as a drinking water disinfectant, in wound care on bandages and dressings, in foams for surgical sutures, in topical creams for burn management, permeated into vascular and urinary catheters, and embedded as particles in microfiber cloth for surgical masks.

The mechanism of action of silver as an antimicrobial is only now being investigated and more understood. Recent studies show that silver is only effective as an antimicrobial in it's ionized form, Ag^+ (Lok *et al.*, 2007; Rai *et al.*, 2009). Because it's the Ag^+ that is effective, it provides broad flexibility, in that it can be integrated in the application in its salt forms AgCl and $AgNO_3$ for immediate Ag^+ release or as silver sulfadiazine for a more controlled release that continues for a longer time period. Metallic silver coated nanoparticles also allows for that controlled release as the metallic silver slowly reacts with moisture converting it to Ag^+. It is thought that silver atoms bind to thiol groups (-SH) in enzymes and subsequently cause their deactivation. Silver forms a stable S-Ag bond with thiol-containing compounds in the cell membrane that are involved in transmembrane energy generation and ion transport (Klueh *et al.*, 2000).

Another proposed mechanism is that Ag^+ enters the cell and intercalates between the purine and pyrimidine base pairs disrupting the hydrogen bonding between the two anti- parallel strands and denaturing the DNA molecule (Klueh *et al.*, 2000). Although this has yet to be proven, it has been shown that silver ions do associate with DNA once they enter the cell (Fox and Modak, 1974).

When considering analytical techniques for determining total silver content, inductively coupled plasma-mass spectroscopy (ICP-MS) is typically the favored technique. Since silver is not ubiquitous and is easily ionized, detection limits are extremely low, generally in the part per trillion (pg/mL) range.

Below are some actual analytical values and a working curve used for the quantitative analysis of silver; note the outstanding linear correlation coefficient (0.9998) obtained for this type of study. Further, we note a limit of detection of 50 part per trillion or 50 pg/ml. The use of ICP-MS thus provides an excellent technique for the determination of silver.

- Accuracy RSD <1.0%
- Precision RSD <1.0%
- Limit of Detection: 50 ppt (pg/mL)