

Antimicrobial silver: uses, toxicity and potential for resistance

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Abstract This review gives a comprehensive overview of the widespread use and toxicity of silver compounds in many biological applications. Moreover, the bacterial silver resistance mechanisms and their spread in the environment are discussed. This study shows that it is important to understand in detail how silver and silver nanoparticles exert their toxicity and to understand how bacteria acquire silver resistance. Silver ions have shown to possess strong antimicrobial properties but cause no immediate and serious risk for human health, which led to an extensive use of silver-based products in many applications. However, the risk of silver nanoparticles is not yet clarified and their widespread use could increase silver release in the environment, which can have negative impacts on ecosystems. Moreover, it is shown that silver resistance determinants are widely spread among environmental and clinically relevant

bacteria. These resistance determinants are often located on mobile genetic elements, facilitating their spread. Therefore, detailed knowledge of the silver toxicity and resistance mechanisms can improve its applications and lead to a better understanding of the impact on human health and ecosystems.

Keywords Silver · Silver nanoparticles · Resistance · Toxicity

Introduction

The transition metal silver, both a precious and an industrial metal, is mined with an estimated production of 24,000 tons in 2012 and has a wide range of applications. Silver is used for coin and metal fabrication, in electrical and electronic compounds and for jewelry. In addition, the broad-spectrum antimicrobial effects of silver are well documented. Already the ancient Greeks used silver preparations for the treatment of ulcers, to stimulate wound healing and as preservative for food and water (Alexander 2009). In fact, silver was perhaps the most important antimicrobial compound before the introduction of antibiotics in the 1940s and is still used today in a wide range of medical applications because of its antibacterial effects and low toxicity to human cells. Examples are the use of silver preparations as topical cream in the treatment of burn wounds (Klasen 2000), in

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