Silver nanoparticles and their role in antibiotic resistance

Abstract

Antibiotic resistance is widely recognized as a global health concern, and has long had its cause attributed to the increased use in agriculture and human medicine. Not only does antibiotic resistance pose a threat to the agricultural industry, but also human health. A recent article by Chitrada Kaweeteerawat, Preeyawis Na Ubol, Sanirat Sangmuang, Sasitorn Aueviriyavit & Rawiwan Maniratanachote studied the mechanisms of antibiotic resistance in bacteria exposed to silver nanoparticles (AgNPs). Bacteria exposed to sub-lethal doses of silver nanoparticles showed increases in antibiotic resistance to a number of antibiotics. Because silver nanoparticles are often used in consumer products and medical appliances due to their antimicrobial properties, this study suggests that the very reason these appliances are often being used, is leading to an increase in antibiotic resistance among pathogenic bacteria.

Introduction

The rapid increase in antibiotic resistant bacteria has caused a marked rise in mortality rate related to bacterial infections that could otherwise be treated with antibiotics. This has left researchers scrambling for new advancements in treatments for antibiotic resistant bacterial. Silver nanoparticles have recently been found to contain many benefits regarding microbes, one specifically being their antimicrobial properties. This discovery has led to an increase in engineered silver nanoparticle-containing production like food storage containers, antiseptic sprays, and wound dressings and bandages. With these developments, research has been conducted to look into the possible unintended consequences of silver nanoparticle use in the environment, the human microbiota and in bacteria. It has been found that when bacteria are exposed to sub-lethal doses of silver nanoparticles, mutations and adaptions occur at the DNA level, leaving the bacteria with more hardy membranes that are less permeable, lesser degrees of oxidative stress, and more resistant to a wide range of antibiotics.

Recent Progress

Currently a lot of the research being done on silver nanoparticles is in regard to their antimicrobial properties and benefits, which is why a study looking into the potential adverse side effect or unintended consequences to their uses and disposal is so important. In “Mechanistic antimicrobial approach of extracellularly synthesized silver nanoparticles against gram positive and gram negative bacteria” authorsv Tamboli, Dhawal P. and Lee, Dae Sung mention a result that *E. coli* exhibited DNA fragmentation after being treated with the silver nanoparticles. What the paper in review does so well at mentioning is that if bacteria are introduced to sub-lethal doses of silver nanoparticls, the exact opposite can happen. Because levels of silver nanoparticles that are dissipated in the environment cannot be controlled or accurately measured, more research should be conducted to evaluate the implications of widespread use of silver nanoparticles and their disposal methods.

Discussion

In this study, *S. aureus* strain ATCC 6538 and E. coli strain ATCC 8739

were used in an attempt to provide two view points of the data in two bacteria, both a gram negative and a gram positive, commonly found in humans. The bacterium were exposed to a sub-lethal doses of silver nanoparticles over different time periods, and then tested against controls to different antibiotics. The results showed that after treatment with silver nanoparticles, staph had a XXX increase in antibiotic resistance, and E. coli showed a XXX increase to penicillin. To shed light on the mechanisms behind the bacterial adaption that ultimately led to antibiotic resistance in the bacterium, several sets of data were collected from the bacterium after treatment with silver nanoparticles, these tests consisted of bacterial membrane damage, cellular oxidative stress, and ATP levels inside the cells. The results showed that pre-exposure to silver nanoparticles caused the bacteria to exhibit more robust plasma membrane that became less permeable to foreign substances (like antibiotics). The data collected also indicated that the bacterium pre-treated with silver nanoparticles showed a lesser degree of oxidative stress silver nanoparticles to untreated controls. This data is consistent with a recent study that showed silver nanoparticles pre-treated E. coli upregulate antioxidant mechanisms (McQuillan and Shaw 2014 as cited in ). Also, cells pre-treated with silver nanoparticles were also found to retain higher levels of ATP molecules compared to the non-treated control in the presence of ampicillin. The bacteria pre-exposed to silver nanoparticles showed a minimal inhibitory concentration increase and a minimal biocidal concentration increase of two- to eightfold. Further investigation was done when the minimal inhibitory concentration was calculated against four antibiotics, all with diverse targets and mechanisms of action in inhibiting bacteria—a cell wall synthesis inhibitor, (penicillin), a 50S ribosome subunit inhibitor (chloramphenicol), a 30S ribosomal subunit inhibitor (kanamycin), and an effective antibiotic against beta-lactamase producing bacteria (amoxicillin and clavulanic acid, also known as Cavumox)—were used. Treatment with silver nanoparticles resulted in a two- to eightfold increase in minimal inhibitory concentration values competed to the un-treated controls in both bacterial with the exaction that the silver nanoparticle treatment did not significantly change the minimal inhibitory concentration value of E. coli when exposed to kanamycin.

Overall silver nanoparticles have a large potential at negatively impacting the environment in a number of ways. Silver nanoparticles have been found in non-lethal concentrations in soil and in water, which has likely led to the same antibiotic resistance development seen in this experiment, but in nature. This poses a threat to human health and continues to deepen the breadth and mode of development of antibiotic resistant bacteria that we see today. This study sheds light on the possible unintended consequences of the use of silver nanoparticles, and specifically their disposal leading to non-lethal doses found in various areas of the environment, and how it is contributing to the rise in antibiotic resistant bacteria. With this information, researchers can explore a new avenue of possible ways to combat the ever-increasing rate of complications and death related to bacteria that would otherwise be treated with antibiotics.

References

Chitrada Kaweeteerawat, Preeyawis Na Ubol, Sanirat Sangmuang, Sasitorn Aueviriyavit & Rawiwan Maniratanachote (2017) Mechanisms of antibiotic resistance in bacteria mediated by silver nanoparticles, Journal of Toxicology and Environmental Health, Part A, 80:23-24, 1276-1289, DOI: 10.1080/15287394.2017.1376727

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