Chapter 3
The Nano Revolution, Metal Nanoparticles in Antibiotic-Resistant Era: Synthesis, Properties, and Antimicrobial Applications

Shilpa Rudra
https://orcid.org/0000-0003-0291-2225
Vellore Institute of Technology, Vellore, India

Danie Kingsley
https://orcid.org/0000-0001-7838-5017
Vellore Institute of Technology University, Vellore, India

ABSTRACT

Nanoparticle synthesis has gained significant interest over the years because of its unique characteristics and sustainable and productive applications in numerous fields. Metals exhibiting a friend-foe relationship with bacteria, possess the potential to inhibit their growth in specific forms and concentrations. The increase in antimicrobial resistance in recent years has drawn attention. Top-down and Bottom-up are the two approaches to metal nanoparticle synthesis. Gold, silver, copper, etc. have been used in medical fields from ancient times. Although these conventional methods of creating nanoparticles are effective and adaptable, they have very negative effects. On the other hand, green synthesis provides an economical and environmentally beneficial substitute by using natural resources. To address the current problem of antimicrobial resistance, this review highlights the antimicrobial activity of metal nanoparticles and highlights their contributions to sustainability, safety and efficiency in nanoparticle production as well as their synthesis process,

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benefits, and drawbacks.

1. INTRODUCTION

Nanotechnology is currently regarded as an intriguing field for research and is gaining continuous, vast, and enormous attention worldwide, (Lee, Jeong, & Kanmani, 2019). Professor Norio Taniguchi first used the term "nanotechnology" in 1974 in his thesis, but it achieved popularity from a book named Engines of Creation – The Coming Era of Nanotechnology written by Eric Dexter, (K.M.A et al., 2008). Nanotechnology includes synthesis techniques, structure, and size modification of nano-sized particles and is featured as a strong platform for metal nanoparticle synthesis, (Kadam et al., 2019). The word "nanoparticle" comes from the Greek word "nano," meaning "small or dwarf," (Ealia & Saravanakumar, 2017). Nanoparticles (NPs) are the particulate matters with at least 1-dimensional particles size ranging from 1-100 nm concerning 1nm equals 10^{-9} or one billionth of 1 meter and demonstrate potential biological activities such as antimicrobial, antifungal, etc. The decreased particle size of nanoparticles to nano-level particle size exhibits improved particle size distribution and morphology and shows a high surface-to-volume ratio. A nanoparticle's surface-to-volume ratio is 35–45% greater than a large molecule. The distinct surface area of NPs contributes to size-dependent strong surface reactivity. The unique and multifunctional characteristics of nanoparticles such as specific size, shape, different compositions, flexibility, ductility, rigidity, quantum size, hardness, and rigidity lead to the great expansion of the application of nanoparticles into various fields including agriculture, food, medical, material sciences, environmental aspects, space technology, magnetism, optoelectronics and electronics, cosmetics, catalytic, and energy use, (Lee, Jeong, & Kanmani, 2019).

Antibiotic resistance, a worldwide health emergency, poses a danger to decades of medical progress. traditional antibiotics are losing their effectiveness against multidrug-resistant (MDR) pathogens, necessitating alternative approaches. Different types of bacteria i.e. *Streptococcus pneumoniae*, Methicillin-resistant *Staphylococcus aureus* (MRSA), beta-lactamase (ESBL) producing *Escherichia coli* are developing as prevalent community spread multidrug-resistant bacteria due to overuse and unrequired overconsumption of antibiotics. NPs synthesized from gold, silver, zinc etc. open promising opportunities as efficient alternatives to antibacterial agents due to their diverse antimicrobial mechanisms such as membrane disruption, destabilization, production of Reactive oxygen species (ROS), and inhibition of cellular process and biofilm formation, diminishing the currently raised global concerns of an antibiotic-resistant era. Three categories of nanoparticles can be distinguished: (a) organic, (b) inorganic, and (c) carbon-based. Ferritin, dendrimers, liposomes,