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APPLICATION OF INNOVATIVE NANOMATERIALS TO RESOLVE IMMINENT ANTIMICROBIAL RESISTANCE

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ABSTRACT

The foremost worldwide community issue of health is due to virulent bacteria and successively increasing antimicrobial-resistant against these microorganisms. The renowned disease control center stated that the world entered a post-antibiotic horizon, where the death rate from the microorganism will be more from cancer disease. In the ongoing period, new techniques such as nanoparticles emerge and are used against the virulent strains of microorganisms. Those difficulties faced by common antimicrobials such as antibiotic-resistant can be overcome by the advancement of nanotechnology. The nanomaterial (selenium, cobalt, silver, cobalt, cadmium, zinc oxide, and magnetic) plays a vital role in the delivery vehicle and surface therapeutic agents for a cargo of antimicrobial drugs. In this review, we presented the use of nanoparticles as an efficient system for antibacterial applications.

Keywords: Antibacterial, antimicrobial resistance, antibiotics, nanomaterials

INTRODUCTION

Antimicrobial resistance (AMR) is the wider term for resistance in different kinds of microorganisms and involves a struggle with antibacterial, antiviral, anti-parasitic, and antifungal drugs. AMR occurs when bacteria change in response to the usage of antibiotics in the treatment of bacterial infections and making them ineffective. Low-quality medicines, wrong prescriptions, and poor infection prevention and control also encourage the development and spread of drug resistance **[1]**. The major obstacle faced in human

health is the new drug resistance in pathogenic bacteria. When the microorganisms become resistant to most antimicrobials they are often referred to as "superbugs". According to predictable assessment, approximately two million cases of severe illness are caused by bacterial antibiotic-resistant and also in United State many deaths annually occurred. It is estimated that in the future the annual death will be million due to bacterial infections, which is more than caused by disease of cancer at present **[2]**. In the persistent antibiotic treatment of multidrug- resistant, most of the cases but in tissue debridement is having a smaller number of cases, the cost of health care boosted, and patient compliance declines. In United State, it was noted that the health and societal cost of these infections is 55 billion US dollars yearly increased **[3]**.

The action of nanomaterial and antibiotic

The mechanism of antibiotics directly targets the synthesis of bacterial cell wall inhibition, which is necessary for bacterial genetic material (RNA & DNA). The intrinsic activity of the bacterial cell quickly emerges by mutation and transfer of DNA by the action of antibacterial **[4]**. In multiple drug-resistant, genetic material from the different organisms can be acquired by these antibiotics which have the antibacterial characteristic. The infection caused by the planktonic and biofilms is minimized by especially designing nanomaterials based on antimicrobial which has high efficacy against biofilms and planktonic infections **[5, 6]**. In this review, we have focused on different kinds of nanomaterials which have the property of antimicrobial by combating multidrug resistance caused by the planktonic bacterial infection. Furthermore, this review is mostly emphasized the nanomaterial efficacy against bacterial infections, as well as on therapeutic agents and delivery vehicles of antimicrobial agents. In the initial study of microbe and nanoparticles interaction by Metch and its co-worker **[7]** designed the bacteria *bacillus cereus* were homogeneously distributed in cetyltrimethylammonium bromide (CTAB)coated gold nano-spheres or nano-rods. This is possible because of the electrostatic interaction between the negative charge present on bacterial cell wall teichoic acid moieties **[8]** and the positive charge present on the nanomaterial surface. In another experiment, the pile of gram-negative bacteria

E. coli bound on mannose substituted gold nanoparticles (NPs). This process was effective because of the pili hair-like morphology present on the bacterial surface, which contains lectin in the rich quantity that mannose-coated nanoparticles NPs **[9]** are perfectly bonded. Based on these

observations, Wang and its companion demonstrated about the cation NPS isolates the toxicity against bacteria **[10]**. In other similar studies, the bacterial membrane coated with nanoparticles indicated that positively charged gold nanoparticles, which have hydrophobicity formed strong aggregation on the bacterial membrane. It is noted by research that the effect of 2mm core diameter gold nanoparticles on gram-positive bacteria (*bacillus subtilis*) lysed rapidly but less toxicity against gram-negative bacteria (e.g., E. coli) **[11]**. The strong interaction between bacterial membrane and specific nanoparticle's function can lead to modifying the functionality as well as influence the membrane structure.

The antimicrobial silver-based nanoparticles utilize free silver ions acting as an active agent. The characteristic feature of silver ions is to damage the genetic material **[12],** electron transport, and membrane of the bacterial cell. While in the case of copper, the nanoparticles have free copper ions that can produce reactive oxygen species, which damage the genetic material and amino acids in bacterial cells. Likewise, the bacteria are lysed by the titanium dioxide and zinc oxide nanomaterial **[13]**. Many nano material's antibacterial mechanisms are to combat superbug drug-resistant. In biotechnological research, the main focus is on the interaction between bacteria and metal nanoparticles.

Gupta and a co-worker **[14]** formulated nanoparticles of mixed charged that have antimicrobial activity against bacteria. Such types of nanoparticles are designed by different concentrations of negatively (MUA) and positively (TMA) charged ligands. Specific nanoparticle ligands concentration (MUA: TMA) in the ratio of 48:50 and 80:20, respectively, can selectively kill the bacteria. Further research work indicates that cation ligands help in the attachment of nanoparticles to the bacterial surface, on other hand the anionic ligand with head group (carboxylate) by the formation of hydrogen bonding in the bacterial cell wall components that cause the cell death by the breakdown of the structural integrity.

Additionally, another study indicates that researchers designing a zwitter ionic ligand with nanoparticles with different charge representations, one positive charge inside the ligand terminal and another positive charge at the outermost layer **[15]**. It is concluded that the antimicrobial activity of the nanoparticles which are outer side was higher as compared to the inner side as being positively charged as well as more effective, depending on the particle size. Nanomaterial helps design organic

nanosystems **[16]** (micelles, liposome, polymeric, and lipid-based nanoparticles) and inorganic nanosystems (selenium, cobalt, silver, cobalt, cadmium, zinc oxide, and magnetic) to combat with antibiotics and act as a powerful tool against bacteria.

CONCLUSION

The utilization of nanomaterials in the area of antimicrobial therapy offers the best and long-term solution to antimicrobial resistance formation, the vast diverse potential effect of nanomaterial with antibiotics and to understand the exact mechanism of bacterial cell death by different target's actions. The main advantages of nanomaterial fabrication of organic and inorganic nano-systems have the profound ability to combine with antibiotics, which can effectively work against antibiotic-resistant bacteria safely.

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