OPINION

Overview of nanoantibiotics

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ABSTRACT

The creation of new antibiotics was required due to the major clinical issues caused by bacterial strains resistant to antimicrobial therapies like antibiotics. Recently, new antibacterial substances termed as "nanoantibiotics" have been found to be nanostructures with particle sizes ranging from 1 nm to 100 nm. In numerous investigations, it has been demonstrated that nanomaterials have stronger antibacterial effects on both Gram-positive and Gram-negative bacteria.

Examples of nanoparticle uses in the biomedical fields include antibacterial nanofilms for medical implants, restorative substances to avoid bacterial harm, and antibacterial immunizations to control bacterial infections.

This opinion emphasizes the importance of nanoparticles and various nanosized materials as antimicrobial agents based on their size, nature.

Key Words: *Nanomaterials; Nanocomposites; Antibiotics*

INTRODUCTION

Due to their nature and qualities, heavy metals including copper, gold, silver, and others have been used as antibacterial agents during the past few decades. Many metal ions can denature and inactivate bacteria, enzymes, and proteins due to changes in their oxidation state. Much smaller metallic nanoparticles can easily enter the bacterium and kill it by destroying its organelles. Nanomaterials have received a lot of attention recently due to their small size, electrical structures, and surface characteristics.

As a result, the topics of optoelectronics, environmental remediation, and modified nanostructures are all heavily explored. Metal oxides and inorganic nanoparticles found in metals (Ag, Cu, Au, etc) (ZnO, CuO, TiO_2, etc.)

Since infectious diseases brought on by pathogenic bacteria are the main cause of death worldwide, they represent a constant threat to public health in all countries. The first known living things on the earth were bacteria, which have since evolved to become robust. One of our civilization's biggest medical triumphs is widely regarded as the invention of antibiotics. About 20 new antibiotics were created between 1930 and 1962 to treat diverse bacterial diseases. Additionally, the pharmaceutical industry's search for ground-breaking compounds with effective antibacterial capabilities is becoming difficult given the dynamic nature of developing infectious diseases. Inappropriate antibiotic use results in resistance to conventional treatments, which kills about 700,000 people annually. After a certain amount of time, it has been proven that employing nanomaterials as antibacterial agents does not cause the emergence of resistance to traditional antibiotics.

However, because nanoparticles are smaller in size, a specific amount (dose) of nanoparticles is required to create an effective antibiotic agent, and, thus, functionalized nanoscopic antibiotics have already been developed in relation to traditional antibiotics predicated on elemental compositions or stoichiometric ratios. Depending on the manufacturing process and the testing conditions, nanoantibiotics have reportedly been reported to be more effective, durable, and less harmful.

Nanoparticles as antibiotic agents

The World Health Organization asserts that several metal-based nanomaterials have demonstrated efficacy against a variety of infections despite their small sizes and specificity for bacteria. Nanoparticles are defined as having a size in the range of 100 nm or less and can work as standalone antibacterial agents or as additives to conventional antibiotics. The significance of nanoantibiotics as superior medications to lower the amount of drug-resistant bacteria in the treatment of diseases was recently proven by Mamum et al. (2021) "nAbts illustrate a potential Trojan horse strategy to bypass antibiotic resistance pathways," claim Mamun et al. Metal-based nanomaterials have been demonstrated to regularly have unspecific detrimental effects on microorganisms.

Effect of combination of nanoparticles and antibiotics

The impact of synergism is linked to the production of extremely active hydroxyl radicals, changes in defence cellular processes, and anti-biofilm effectiveness. Contrary to the impact of using antibiotics in clinical practise, which minimises antibiotic doses, exposure duration, and bacterial resistance, the use of antibiotics in association

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with nanostructures is very effective in boosting antibiotic functionality. Most dangerous germs are resistant to common antibiotics. To increase the effectiveness of antibiotics, nanoparticles are attached to them. NPs combat pathogenic microorganisms through a variety of mechanisms that are simultaneously activated by nanoparticles and antibiotics.

According to research, adding silver nanoparticles to several medications enhances their overall effectiveness against *Escherichia coli.* These medications include cefuroxime, azithromycin, fosfomycin, cefoxime, and chloramphenicol. Although compared to medicines alone, the antibacterial efficacy of silver nanoparticles in combination with oxacillin and neomycin was observed to be less effective against Staphylococcus aureus, the addition of zinc oxide nanoparticles to antibiotics increased the antibacterial efficacy.

INORGANIC NANOPARTICLES

The inorganic nanostructures made of metal and metal-oxide have shown excellent results in the treatment of antibiotic resistance. Nanomaterials behave differently than antibiotics, demonstrating their effectiveness against diseases to which the host has developed immunity.

Silver nanoparticles as antimicrobial agents

Ag NPs possess antiviral, antifungal, and antibacterial properties. Ag NPs have the capacity to penetrate the cell walls of bacteria, altering the cellular structure and, therefore, causing cell damage. When Ag NPs interact with bacteria, they aggregate at the membrane and form complexes, causing abnormalities that result in cell death. This is because nanomaterials have narrower diameters and bigger exposed sites than conventional materials. It is believed that Ag NPs continuously emit silver ions. Using Coptis chinensis, Pei et al. produced Ag nanostructures with a nano range of 6 nm-45 nm (CC). The researchers evaluated AgNPs for resistance to *Aspergillus niger*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Bacillus subtilis*, and *Staphylococcus aureus*.

The findings showed that at increasing concentrations (25 L/mL, 50 L/mL, 75 L/mL, and 100 L/mL), the Ag NPs had a noticeably weaker effect on the *A. niger* and were particularly reactive with *B. subtilis*. The AgNPs were discovered to rapidly generate diffusible suppressive species from bacterial membranes throughout the incubation process.

Copper nanoparticles as antimicrobial agents

The majority of life forms contain copper, an abundant metal that is also a vital mineral. Numerous applications of copper nanoparticles exist, including electrochemical sensors, optoelectronic devices, solar panels, paints, and varnishes. Datura leaf extract was used by Parikh et al. to create copper nanoparticles. The antibacterial activity of the copper NPs against *E. coli*, *Bacillus megaterium*, and *Bacillus subtilis* surpassed that of ordinary chloramphenicol, proving that copper NPs can be utilised as antimicrobial agents rather than antibiotics. Chitosan was utilised as a stabiliser to prevent the deposition and quick oxidation of chemically created copper nanoparticles with diameters ranging from 2 nm-350 nm.

Titanium dioxide nanoparticles as antimicrobial agents

Due to their distinctive qualities, such as bactericidal photo catalytic activity, security, and self-cleaning capabilities, titanium dioxide (TiO_2) NPs are among the most frequently explored nanomaterials for antimicrobial applications. They have a lot of potential for use in food packaging and containers as bactericidal and fungicidal agents. TiO_2 NPs produce Reactive Oxygen Species (ROS) with a high oxidising potential when exposed to light, which causes a shift in the band-gap in the open atmosphere (O_2). The role of TiO_2 NPs in regulating the growth rate of *Pseudomonas aeruginosa* isolated from the endotracheal tract, pus, alveolar lavage, and sputum was examined by Arora et al. They found that subjecting TiO_2 nanoparticles to UV light for 60 minutes significantly increased their antibacterial activity against drug-resistant *P. aeruginosa* (MDR).

ORGANIC NANOPARTICLES

The majority of the components of organic-based carbon nanostructures and nanocomposites are organic. Organic nanoparticles like liposomes, micelles, dendrimers, and polymeric NPs are changed into the desired shapes via non-covalent interactions. Organic antibacterial agents have been discovered to be slightly less stable than inorganic substances at specified temperatures.

Liposome

For both hydrophobic and hydrophilic medications, liposomes offer a safe biological delivery system. Antibacterial liposomal medications are often given intravenously. For the targeted administration of many medications and antibiotics, liposomes are essential. Researchers have created injectable dose versions of nystatin, amphotericin B (AmB), and liposomal polytene macrolide antibiotics. In a mouse model of pulmonary aspergillosis, AmB-Encapsulating PEG Liposomes (PEG-L-AmB) with the ideal lipid composition were reported to be less deadly and more effective than conventional AmB formulations .Additionally, researchers have shown that the liposomal encapsulation of immunomodulators that stimulate macrophages can be employed to try and lessen the toxicity of these medications while directing them to cells in mononuclear phagocyte organisations to foster nonspecific resistance to illnesses.

Dendrimers

A variety of dendritic shapes, including diverging cores, ending parts, reinforcements for structures, and building components and linkages, can be found in metals. Due to their distinctive characteristics, including their enhanced surface area and relatively tiny size, dendrimers are recognised as effective NP carriers for the administration of antimicrobial drugs. Dendrimers with high-molecular-weight functionalized components can outperform the linked molecule's antibacterial activities. Extreme caution must always be exercised while choosing antimicrobial targets. Larger dendrimers may have trouble reaching the antibacterial target because they cannot cross the cell membrane barrier.

Lignin

In recent years, lignin and lignin nanoparticles have become reliable and efficient drug delivery vehicles. Additionally, their direct antimicrobial actions have been used. The fact that lignin nanoparticles are abundant in nature, affordable, and advantageous to the environment is a huge benefit. This is due to the fact that lignin is mostly sourced from plants, and when it is produced from plant waste, it is both economical and environmentally responsible. The use of lignin as a drug-carrier molecule has been covered in a number of studies in the literature. According to Lintinen et al. (2019), lignin nanoparticles are quite effective at killing Gram-positive bacteria. Additionally, the researchers produced a colloidal solution of lignin and silver that they used as an antibacterial agent.

CONCLUSION

Most bacterial strains now exhibit increasing resistance as superbugs due to the widespread usage of conventional antibiotics. This is becoming into a significant threat to public health on a global scale, necessitating the development of novel antibacterial and other protective chemicals to counter the danger. Numerous nanomaterials are highly suited to serve as powerful antibacterial agents due to their small size and high aspect-to-volume ratio. Additionally, nanoparticles show sufficient biocompatibility when combined with scaffold materials. Particularly fast-acting and challenging to produce and isolate are antibiotics. Contrarily, nanoparticles and nanostructures offer sustained antimicrobial activity with very little side effects. The antibacterial abilities of CNTs and other organic nanoparticles have been proven.