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Review Article

Nano Biotechnology, Usage, Application and Challenges in Microbiology (Mini Review)

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Abstract— Nanotechnology is a broad scientific discipline that has permeated almost every branch of study. Nanotechnology has significant applications in various fields such as environment, agriculture, industry, and medicine. It is particularly valuable in the diagnosis and treatment of microbial illnesses caused by bacteria, fungus, and viruses. This article provides concise explanations regarding the utilization of nanotechnology in the food industry and provides a summary of the various applications of nanotechnology in the field of microbiology. The discussion revolved around the applications of nano-particles, such as their antibacterial activity, as well as the use of nano-sensors for detecting microbes. However, it is necessary to take some measures while utilizing nanotechnology applications in order to prevent any potential toxicological and adverse impacts on both human health and the environment.

Keywords— microbiology, nanotechnology, nanoparticles, antibacterial, antibiotic, Nano biotechnology

1. Introduction

Microbial nanotechnology (MN) is a growing field that uses nanotechnology and microorganisms to create unique materials. It has applications in bioremediation, energy generation, medicine, and agriculture. MN has been used to treat industrial effluents, fabricate biosynthetic nanoparticles, and improve medication delivery, imaging, and cancer therapy [1-3]. Microbial nanotechnology shows great potential and is a fascinating subject of study that has substantial implications for other disciplines.[4].

Nanotechnology is essential in the study of microbiology. Nanotechnology mostly serves to diagnose germs and address the infections they induce. Thankfully, there are various techniques currently in use to apply nanotechnology for the detection and treatment of diseases caused by diverse microorganisms, including bacteria, viruses, and fungi. The extensive utilisation of nanotechnology in microbiology has resulted in several benefits, such as rapid and cost-efficient diagnosis, as well as quick and effective therapy that has the potential to shorten the duration of treatment. Moreover, the application of nanotechnology in the field of microbiology has resulted in the discovery of novel approaches for the diagnosis and treatment of infectious diseases [5,6].

Presently, nanotechnology is employed for the purpose of controlling and distinguishing different categories of bacteria, encompassing both gram-negative and gram-positive variants. The specified microorganisms are Bacillus subtilis, Escherichia coli, Nocardiopsis spp., Acinetobacter baumannii, Klebsiella pneumoniae, Pseudomonas aeruginosa, Mycobacterium tuberculosis, Salmonella Typhi, Proteus mirabilis, Vibrio cholerae, and methicillin-resistant *Staphylococcus aurous*[7-9], inclusive. Furthermore, nanotechnology is essential in the realm of virology, particularly in identifying and managing diseases caused by various viruses such as Human Immunodeficiency Virus (HIV), Influenza virus, Ebola virus, Zika virus, and SARS-CoV-2 [10,11].

Nanotechnology has been utilised in mycology to detect and cure several fungal diseases caused by pathogens such as Candida albicans, Cryptococcus, Pneumocystis, and Blastomyces [12,13]. In addition, microorganisms have the capacity to function as active production facilities, producing nanomaterials with specific and focused functionalities. Scientists can genetically manipulate microorganisms to create nanostructures with enhanced properties, including stability, compatibility with living organisms, and targeted interaction with biological systems [14].

Microbial nanotechnology offers potential for innovative drug delivery due to its small size, high surface-to-volume ratio, and surface modifiability [15]. This approach enhances treatment efficacy and reduces adverse effects. However, ethical considerations, safety assessments, and regulatory frameworks are needed for responsible development. Multidisciplinary cooperation among microbiologists, materials scientists, engineers, and medical specialists is also crucial [16].

The objective of this work was to analyze, evaluate, and examine the research on the utilization of nanotechnology for diagnosing and treating diverse diseases caused by distinct microorganisms.

2. Biosynthesis of nanomaterial's using microorganisms

The application of physical and chemical methods for the production of nanoparticles has shown great efficacy, decreased time requirements, and remarkable effectiveness. However, the increasing production of metal nanoparticles and oxides using chemical and physical methods is showing harmful effects on the environment when they are released. Hence, the procedure of producing nanoparticles by employing microorganisms like bacteria, fungi, viruses, yeasts, and algae, commonly referred to as 'Green synthesis' or 'Biosynthesis', is gaining considerable interest. Different bacteria utilise unique methods to produce nanoparticles.

[16]. Typically, nanoparticles are generated through the following process:
(i) Metal ions are first trapped on the surface or inside microbial cells.
(ii) The trapped metal ions are then converted into nanoparticles through enzymatic reduction.
Currently, a wide range of inorganic nanoparticles with precise chemical composition, size, and shape have been created with the use of different microorganisms. Nanoparticles have been extensively studied for their potential applications in diverse advanced fields such as targeted drug delivery, cancer treatment, gene therapy, DNA analysis, antibacterial agents, biosensors, acceleration of chemical reactions, separation science, and magnetic resonance imaging (MRI) [17]. There has been a comprehensive investigation into the use of silver-based antiseptics in response to the increasing and widespread resistance of bacteria to many antibiotics in recent years. The scientists Dura´n, Marcato, De Souza, Alves, and Esposito have documented the use of the fungus Trichoderma viride in the production of silver nanoparticles. The study conducted by [18] demonstrated that silver nanoparticles produced by Fusarium oxysporum can be integrated into textile materials to effectively prevent or reduce infection caused by harmful bacteria, such as S. aureus [19].

Researchers have recorded the formation of spherical selenium nanoparticles by Bacillus subtilis. The diameter of these nanoparticles ranges from 50 to 400nm. They demonstrate a significant proportion of surface area to volume, robust adhesive capacity, and compatibility with living organisms. The nanoparticles were used as enhancers and stabilisers in an HRP (horseradish peroxidase) biosensor. Moreover, the use of magnetic particles that are linked to biological molecules has been suggested as a highly effective approach for constructing assay systems and serving as a biological indicator. Chemiluminescence enzyme immunoassays, utilising antibodies immobilised on BacMPs, have been developed by scientists and have proven to be highly efficient. These tests are designed to quickly and precisely identify tiny compounds, such as environmental contaminants, hormones, and harmful detergents[21].

Nanoparticle biogenesis is attracting attention in several industries due to its simplicity, cost-effectiveness, and environmental compatibility. However, it is essential to conduct a thorough analysis of the cellular, molecular, and biochemical mechanisms involved in the creation of biological nanoparticles in order to improve their application in many industries.

3. Antimicrobial Effect of Nanoparticles

The silver-silica nanocomposite included into the polystyrene material acts as a potent antimicrobial agent, inhibiting the growth of germs upon contact with its surface. According to reference [22], materials that are treated with the silver nanocomposite have strong antibacterial properties. Cationic peptide nanoparticles can assume either α-helical or β-sheet-like structures, allowing them to enter and then damage the negatively charged surfaces of bacterial cells. The self-assembled nanoparticles composed of an amphiphilic peptide exhibit potent antibacterial activity against various bacteria, yeasts, and fungi. The nanoparticles exhibit significant therapeutic efficacy in the treatment of Staphylococcus aureus infection in mice][23].

Nanocapsulation can be used to integrate antibacterial properties by employing nanotechnology. Donsi et al. [24] discovered that incorporating essential oils into nanometric delivery devices and adding them to fruit juices improves their antibacterial efficacy without significantly affecting the overall quality of the final product. Ravichandran et al. [25] found that adding benzoic acid (1,100 μg/mL) to polylactic-co-glycolic acid nanoparticles effectively prevented the growth of Listeria monocytogenes, Salmonella typhimurium, and Escherichia coli in raw materials. The antibacterial efficacy of titanium dioxide (TiO2) and silver oxide (Ag2O) nanoparticles has been proven to be substantial. In addition, they can also be efficacious against eukaryotic pathogens [26]. Silver nanoparticles can be produced by a simple and eco-friendly method called green synthesis. This approach entails employing the extract derived from the leaves of Plectranthus amboinicus, which performs the dual function of reducing and capping agents. The examination of morphology indicates the formation of nanoparticles that exhibit a near-perfect spherical shape. The silver nanoparticles exhibited enhanced antibacterial effectiveness against Escherichia coli and Penicillium spp. in comparison to other tested pathogens, as evaluated by the disc diffusion method [27].

Utilising nanoparticles for the delivery of benzoic acid demonstrated efficacy in decreasing the population of S. typhimurium and L. monocytogenes bacteria. After 9 and 14 days of storage, samples lacking nanoparticles showed a decrease of 1.0 and 1.6 log CFU/g in S. typhimurium, and a decrease of 1.1 and 3.2 log CFU/g in L. monocytogenes, respectively. The study's findings demonstrate that phenolics, when delivered via nanoparticles, are efficacious natural compounds for pathogen reduction. Additionally, these data indicate that phenolics show potential for use in commercial safety applications.When compared to traditional management techniques, nanoscale packaging increases the rate of braking and extends the duration of antibacterial effectiveness. Additionally, Chopra et al. [28] evaluated the antibacterial efficacy of nanoscale capsules transported by nanoscale. The outcomes showed that, under carefully controlled laboratory settings, closed nanoscale capsules exhibited enhanced antibacterial efficacy against luteus microcoxes, Pseudomonas aeroginosa, Salmonella Intric, and Eropactor arogines. Furthermore, it was observed that this effect outlasted the antibacterial qualities of the individual ingredients when evaluated separately, lasting more than six months.

4. Applications of Nanotechnology in Medical Micro Biology

The achievements of nanotechnology have received considerable attention because of their potential applications in medical biology, pharmacology and immunology. A variety of nanotransmitters, including polymeric nanoparticles, fat, germ, insects, throw-away, potty-nanoparticles, polymeric spouses, carbon/minerals and biological-based nanoparticles, have been developed to efficiently transmit diagnostic effects, leading to encouraging results. (refer to Figure 1). Various therapeutic ingredients, such as medicines, genetic materials, proteins, serna and eptides, are being delivered more precisely to target precisely wet tissue. Nanomedicine is at the forefront of progress in promoting the timely identification, treatment and evaluation of cancer, Parkinson's disease, Alzheimer's disease, tuberculosis and ophthalmology.

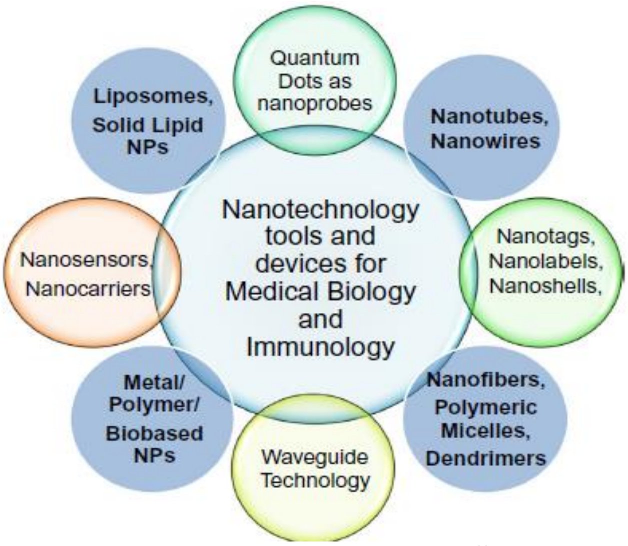

Fig-1- This is a schematic diagram illustrating different bio-nanotechnological instruments and equipment used in the fields of medical biology and immunology.

Nanotechnology is essential for the development of biological chips because it enables the identification and examination of individual chemicals and cells, leading to notable improvements in molecular diagnostics. Scientists have recently developed nanoparticles that are chemically associated with biological molecules, such as antibodies, peptides, proteins and nuclear acids. Nanoparticles are used as nanoparticles to detect substances and determine their properties at the molecular level. Functional nanoparticles provide a direct, rapid and highly sensitive way to detect the virus [29].

Waveform technology is an advanced tool used in nanomedicine for rapid detection of pathogens. An exhibition of technology applications for detection of Herbes Simple Type 1 Virus (HSV-1) was presented through the introduction of Herbez antibodies into a wave channel. The technique has successfully identified the virus in different concentrations, ranging from 103 millilitres to 107 millilitres. The method is a very diverse one, because it allows the use of any antibody to obstruct a channel to detect [30].This device has the ability to identify various viruses, including HIV/AIDS, severe acute respiratory syndrome, HBV, HCV, avian influenza (H5N1), and others [31].

The detection of avian influenza virus involves capturing the virus on a flat optical waveguide, adjusting the index of refraction due to binding to antigen-specific antibodies [33].

5. Toxicological and negative effects of nanoparticles

The potential health risks associated with chemicals and nanoscale additives in food and drink have thus been raised by the application of nanotechnology. These worries have arisen because a plethora of scientific studies show that engineered nanoparticles are able to easily transcend biological barriers. Furthermore, certain nanoparticles may enhance the production of oxidants, potentially causing oxidative damage to cells [34].

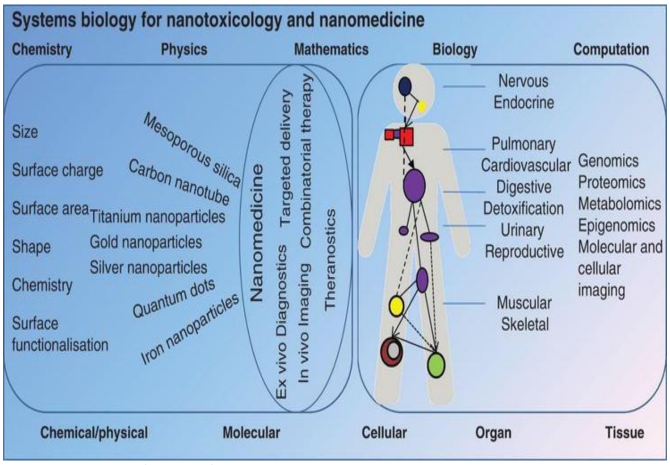

Fig2. For the safe use of nanomaterials in therapeutics, it is important to have a thorough understanding of the characteristics and behaviours of these materials at all levels of biological organisation. Gaining more knowledge in this area involves collaborative research efforts that involve multiple disciplines.

To improve the barrier properties of filling materials, nanoparticles such as silicate nanograms, nanoscale stacking, nanosilver, magnesium, and zinc oxide are utilized. Nanoparticles must migrate in order to interact with food in food packaging materials. The research found that there was minimal mineral migration from vegetable samples to biodegradable ecstasy/composite nanocopper films, which are frequently used in food packaging due to their gas barrier qualities [35].

Furthermore, Empeleteri et al. [36] found that approximately 50% of the nanoparticles in the sock underwent an instantaneous conversion to silver chloride (AgCl) when silver nanograms were exposed to a solution containing hypochlorite and detergents. They propose that an oxidation process is necessary to convert Ag nanoparticles into AGCl. Furthermore, washing fabrics in solutions containing oxidizing agents may reduce or eliminate the effectiveness of silver in killing germs in textiles. In three commercially available samples of nanosilver plastic food containers, the phenomenon of silver migration was observed during an independent experiment. Between 1.66 and 31.46 mg per cm of silver were migrated overall [37-40].

6. Conclusion and future studying

Microbial nanotechnology is utilized in soil remediation to effectively remove pollutants and heavy metals from contaminated soils by creating nanoparticles that attach to and remove pollutants[41-45].

Microbial nanotechnology enhances crop growth and yields by generating nanoparticles used as fertilizers, insecticides, or herbicides, releasing nutrients and compounds for long-lasting benefits[46] .

Microbial nanotechnology can effectively control diseases by producing nanoparticles targeting harmful microorganisms. These nanoparticles, such as silver, copper, or zinc, can kill fungi or bacteria. Microbial nanotechnology can also improve water management in agriculture by absorbing and releasing water, reducing irrigation requirements and promoting water usage efficiency. Further research is needed[47-50] .

Microbial nanotechnology can promote sustainable agriculture by developing eco-friendly farming techniques, optimizing resource utilization, and reducing chemical consumption, thereby enhancing the advancement of agroecosystems[51].

This Special Issue explores the use of microorganisms in nanomaterial manufacturing, emphasizing the need for standardized procedures and addressing existing knowledge and challenges in the microbial synthesis process.
Advancements in biosynthetic pathways and genetic engineering have led to microbial-based nanosynthesis, promising commercial applications in sensor-based devices, diagnostic tools, and disease management[52].

This Special Issue explores the potential of microorganism-produced nanoparticles in eliminating toxic metals from the environment. It covers methods, characteristics, practical applications, legal structures, risks, and challenges in biomedicine, environmental science, and agriculture, focusing on microbial-based nanosynthesis [53].

Significant progress has been made on the subject of nanotechnology in terms of the installation, characterization and understanding of nanomaterial mechanisms by physical or chemical methods. While subsequent processes have been effective and require less time, the resulting metallic oxides and particles have had environmental toxic effects when released to the environment. In order to address these problems, it is necessary to take advantage of the process of "biogenesis" or "green formation" of nanoparticle using microorganisms [54-55].

This methodology has received the attention of scientists in recent years because of the distinctive characteristics, biocompatibility, a wide range of uses, cost-effective production methods and environmental sustainability demonstrated by the resulting nanoparticles. Furthermore, the process of manufacturing nanoparticles using environmentally friendly methods is sometimes referred to as a green combination. In addition, there is a wide range of natural biological resources, including plants, algae , fungi , osteoporosis, bacteria, viruses and microbe secondary metabolites , used in the manufacture of these nanoparticles [56].

In summery , microbial nanotechnology has great potential in various industrial applications, such as the detection of pollutants, the dismantling of pollutants in industrial wastewater and the elimination of heavy metal ions. Nanotechnology has many uses in food microbiology, including food processing, food packaging, food safety, detection of food-borne pathogens, and extension of the life expectancy of food products. The integration of nanotechnology and clinical microbiology has the capacity to offer new solutions to address health issues in a logical manner. This can be achieved through the use of nanotechnology tools in clinical microbiology or through the effective use of microorganisms to produce nanoparticles of medical interest[57-59].

Conflict of interest statement
The author declares that she has no conflict of interest in this work.

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Ruqaya Muther Jalil Ewadh work conceived the idea and wrote the original draft of the manuscript, and the author reviewed and edited the final version.

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