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RESEARCH ARTICLE

Application of Various Biogenic Metal Nanoparticles (MNPs)

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Abstract

Biogenic metal nanoparticles (MNPs), synthesized using biological entities, have emerged as a sustainable and versatile tool in various scientific and industrial domains. These nanoparticles exhibit unique physicochemical properties, making them suitable for diverse applications. This review focuses on the myriad applications of biogenic MNPs, emphasizing their role in agriculture, medicine and environmental remediation. In the medical field, biogenic MNPs have demonstrated remarkable antimicrobial, anticancer, and drug delivery capabilities. In environmental remediation, biogenic MNPs contribute to water purification and pollutant degradation, offering eco-friendly solutions to global environmental challenges.

Keywords: Application, Antibacterial, Biosensor, Drug discovery, Gene therapy, Wastewater treatment.

Introduction

Investigation focused on the generation of MNPs through an exogenous method, utilizing plant extracts in place of production techniques. Such method never involve a complex procedure like intracellular synthesis, several purification steps, or the upkeep of cellular cultures. During synthesis process, reactions are typically conducted while few techniques may involve mild warming. That's widely recognized for certain biomass possess biomedical properties. Therefore, they can serve as natural sources of reducing agents. Based on this understanding, plants with medicinal attributes were chosen for this purpose (Nazeruddin et al., 2014).

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Researchers have embraced green synthesis methods for creating various forms, focusing on standardization and application, given the significant amount of research for synthesis of MNPs. MNPs, including Au, Ag, ZnO, produced using biological material through generation techniques. As mentioned earlier, the green synthesis method is favored over other approaches due to its ease of use, reproducibility, and consistent material organization. The synthesis of Ag NPs garnered more attention because it is quick, cost-effective, non-pathogenic and environmentally friendly. Various biomolecules found in plants, including alkaloids, amino acids, enzymes, and proteins, have been recognized as potentially therapeutic and environmentally safe (Hameed 2019).

Furthermore, changes in pharmacokinetics enhance healing results to raising levels. In contrast to earlier studies, the current focus is on the localized effects of drugs, emphasizing the importance of directing the drug to a specific location and sustaining its concentration there for an adequate duration to achieve improved outcomes (Mahde et al., 2022). Inorganic nanoparticles and composites of nanoparticles with biomaterials have demonstrated considerable potential in novel procedures of validation and characterization. Due to great ratios, certain NPs display biomedical properties, diminutive, penetrate microorganisms effectively (Huang et al., 2012). Additionally, their photocatalytic, ionizing, and catalytic abilities have resulted in their extensive application in combating human disease-causing microbes, such as viruses, bacteria, and fungi. Numerous researchers have explored

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the properties of owing unique characteristics. Because of inert characteristics, simple fabrication, commonly utilized. Perovskite compounds can be synthesized under various methods, including the milling techniques, and co-precipitation. Furthermore, carbon-based nanomaterials have recently shown significant potential for several biomedical applications (Yadav and Mohite, 2020).

Applications of MNPs

Metal nanoparticles possess distinct and specific characteristics such as conductivity, catalytic abilities, biocompatibility, and a high ratio of outer part with size and mass. These NPs display specific characters, leading to numerous medicinal properties. MNPs produced recognized for their diverse range of uses across various fields as well as several areas as mentioned in Fig. 1 (Das et al., 2018). Aim for synthesizing eco-friendly nanomaterial for minimize garbage as well as create conventional methods. Gather, stabilize, manufacture MNPs, greater variety for innovative material and remaining eco-friendly materials as anticipated for utilizing. Such materials should be used due to many purposes, especially like possible medicinal functions, include bioactivity because of secondary metabolites. It involves investigating several different characteristics by meet the required use across different sectors. Such eco-friendly methodologies which utilize safe process in the advancement for emerging new technology for sustainable management (Nair et al., 2022). Substance for crop improvement, which supplies essential elements needed for promote crop development and high yield while enhancing organic minerals for addressing need of micronutrients. Nano-fertilizers could enclosed for improve mineral uptake, that minimizes waste, fosters quality growth, as well as enhances production (Adisa et al., 2019). Effectiveness for traditional crop improving agents is inherently restricted because of inadequate presence of various elements than the need. This can result from both the underutilization of crops as well as ineffective supply. Nano-fertilizers have been proposed as a potential solution, to enhance yield regarded as smart delivery systems. By using various combinations, nano-fertilizers can be segregated in distinct kinds (Sharma et al., 2019).

The application like conventional could continuously supply for controlled type, currently very important used in many sectors (Gomez-Merino et al., 2018). Incorporation involves controlled distribution for particular substances, especially fertilizers. Studies have been conducted to assess how plants respond to metallic nanofertilizers like Fe, Zn, Mn, and Cu, Ti, Al. Today, advantage for targeted, gradual nutrient release that regulates plant growth is derived from nanobased solutions. This boosts the efficiency of fertilizers, extending the time as well as decreasing eco-toxicity to consequence (Mittal et al., 2020). Depending on the plant's absorption capabilities, fertilizers can either be sprayed onto the leaves or injected into the soil. In agriculture, it utilized as nanoherbicides, nanocoatings, etc.

Nanoparticles have extensive uses in drug delivery, primarily because of two key characteristics. Firstly, their small size allows for easy bioavailability and distribution at specific place since nanoparticles can readily navigate through tiny capillaries and be taken up by cells. Secondly, using biodegradable materials in the fabrication of nanoparticles enables drug delivery take place in a short time duration. The drug delivery process often incorporates significant amounts by specific substrate for nanoparticle fabrication, which may impact toxicity (Mukherjee et al., 2014). Carcinogenicity metallic nanoparticles affected through various parameters; these are crucial for significant

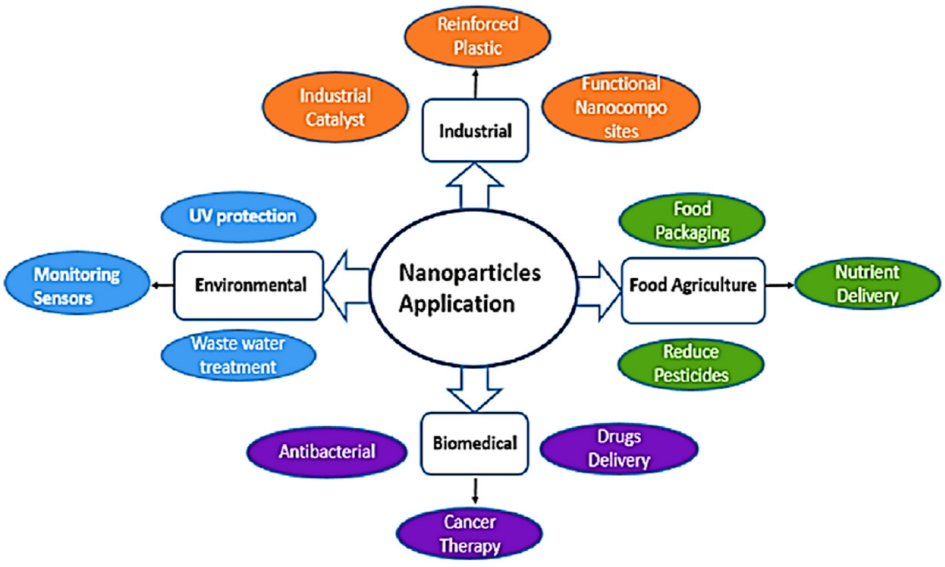

Figure 1: Diagram for different applications of NPs (Khan et al., 2023)

process, particularly concerning absorbance, distribution and metabolism (Parida et al., 2016). Moreover, nanoparticles are significantly serve combining agents in detection of some acute and chronic diseases, e.g., AuNPs recognized for their ability to enhance X-ray differentiation, aiding in quick identification for vascular diseases. AgNPs utilized for dentistry tools as well as cleaning materials (Gour and Jain, 2019).

In nations with limited societal development, microbial transmitted disorders present serious danger in society. Although numerous molecules created for combat such transmission, emergence in different category have hindered conventional medicines' effectiveness against microbial diseases, therefore, an urgent need of antimicrobial solutions (Engler et al., 2012). Recently, therapies based on nanotechnology have been widely employed to identify and treat illnesses and to create novel pharmaceuticals. Among the various nanoparticles as evaluated against various human pathogenic microorganisms, demonstrating significant results. As per reports, nanoparticles produced exhibited notable effectiveness against pathogenic bacteria (Ezhilarasi et al., 2018). Similarly, nanoparticles that were displayed remarkable antibacterial properties. This difference could because of attributed some variations in cell wall of different bacteria, allowing to penetrate easily that cause greater efficacy. An additional cause might the variation in wall composition and layers. Consequently, serves less to permeability which limits entry to reactive oxygen species. Such properties against pathogenic bacterial isolates is well documented (Saleem et al., 2017). Treated bacterial cells with nanoparticles exhibited signs of damage their external membrane, which indicating nanoparticles' significant efficacy. Additionally, Gram-negative bacteria exhibited more pronounced morphological changes compared to Gram-positive bacteria, likely due to differences of layers. In addition, substantial potency noted even after nanocrystal-treated cotton fabrics were washed multiple times. The precise mechanism underlying such significant effect for nanoparticles remains unexplored. Nonetheless, several mechanisms of action have been proposed, like ROS production, damage the plasma membrane, release antimicrobial ions (Khalil et al., 2018). Many investigations indicated the stress induced by production of ROS can be principal factor contributing to the antibacterial properties of nanoparticles. Generation various ROS is linked to activation by ultraviolet and visible light (Yuvakkumar et al., 2018). Hydroxyl and superoxide radicals carry an excess negative charge, preventing them from penetrating the cell membrane; in contrast, hydrogen peroxide can easily enter cells, leading compromising, protein, mitochondria inside may damage. Effectiveness for nanoparticles is influenced by various properties. Like, outer part for nanoparticles lead to increased production of ROS on their surfaces, resulting in enhanced antimicrobial properties (Ramalingam et al., 2019). In addition to reactive oxygen species synthesis, interact to nanoparticles subsequent inhabitation caused. Such effects by nanoparticles caused the to increase the porosity, cell shrinkage, breakdown. Similarly, imperfections in symmetry and their adsorption onto cell surfaces can lead to cellular damage, which contributes to their antibacterial capacity (Srihasam et al., 2020).

Cancer is often triggered through endogenous feature, like genomic damages, which arise in regular cellular development, resulting in uncontrolled undifferentiated proliferation for atypical cellular part, which form tumor. These genetic changes lead to the gene activation, that in turn signal suppression for tumor responsible for regulating cell division and growth (carcinogenesis). As a result of these mutations, the abnormal tumor cells acquire distinctive characteristics, including enhanced replication ability, increased expression of growth signals, uncontrolled proliferation, and a capacity to invade surrounding tissues and evade programmed cell death i.e., apoptosis (Maiyo et al., 2017). Standard cancer therapies like chemotherapy, radiotherapy, and surgery fall short of completely curing the disease, as they may prolong a patient's life but also result in significant adverse effects (Malinga et al., 2021). For example, delivering anticancer medications intravenously during chemotherapy often causes toxicity, as molecules affect cancerous. Moreover, administration these agents can lead to the emergence of resistance, commonly referred to as multidrug resistance (MDR) (Zimmermann et al., 2014). When these drugs are used individually, their therapeutic effectiveness is often limited due to systemic degradation occurring prior to reaching the target site, which ultimately diminishes their bioavailability. Therefore, safer, more effective, targeted which serve as preferable. Specific MNPs those synthesized using green methods, have surfaced as potentially favorable options for anticancer therapies, diagnostic tools, owing specific characteristics, environmental, absence of hazardous effects, biological properties, certain attributes, as well as a versatile can be conjugated specific ligands (Basiuk and Basiuk, 2015). Marketed standard drugs could be comparable that exhibits superior characteristics. Moreover, the combination of plant-metal nanoparticles can be leveraged to attain unique medicinal effects. The eco-friendly synthesis of metal nanoformulations has gained significant targeted capability for improve their role on naturally derived compounds within preparations (Qanash et al., 2023). These developments are aimed at maximizing their enhanced therapeutic efficacy in the context of diabetes prevention and control (Deng et al., 2019).

Biosensors utilizing nanotechnology can assist the aquaculture sector in controlling microbial populations. Researchers has created material that employs sensitized

nanocomposites to identify minuscule amounts of pathogens in water and food. Silver nano is valuable enzymes, serves in many reactions. That functions through deactivating as crucial of broad spectrum. Unlike antibiotic-resistant bacterial strains, colloidal silver is not linked to the emergence of such strains. Silver nanoparticles can even eliminate methicillin-resistant *Staphylococcus aureus* (MRSA). Innovative tracking nanosensors, suchlike under development, that could equipped as relay information for their internal system. Such kind for facilitate the management of fish or intelligent cage systems (Moges et al., 2020).

Food packaging presents significant challenges that directly impact on wellbeing. A packaging system that not only extends, but provides information regarding its quality. Nanotechnology is crucial in this scientific area. Metal nanoparticles have demonstrated their potential to enhance food packaging systems. Effective food packaging is vital for ensuring food safety. It serves as a reliable method that can cause safe from diseases. Food packaging consists of both primary and secondary layers. Secondary packaging typically focuses on aspects such as transportation, storage, and delivery (Berk 2009). Recently, "Nano food packaging" (packages created using nanoparticles) has attracted considerable attention in the food sector. However, concerns regarding the toxicity associated with nanoparticles are significant. Researchers continue to debate safety issues related. Innovative as well as effective based on address challenges in the food industry, including product safety, material performance, economic factors, and environmental advantages (Jagadish et al., 2018). Numerous industries, particularly food processing and packaging, could benefit from utilizing these nanoparticles as antimicrobial agents applied to surfaces. Zinc oxide is utilized and vital for human and animal health (Silvestre et al., 2011). By extending lifespan, diminishing spoilage, acting substances, enhance overall properties. Nanoparticles produced as by-products with unique characteristics (Aguilar et al., 2018). Common antibacterial agents include Ti, Ag, ZnO, Se, Cu, Mg, and Au (Hoseinnejad et al., 2018).

Significant research has been conducted in areas such as drug delivery, cancer therapy, radiosensitizers, bioimaging, wound healing, wastewater treatment, biosensors, and oil recovery. Investigating the potential of nanoparticles' absorption characteristics for addressing oil spills in oceans, capturing greenhouse gases like carbon dioxide, and filtering microplastics from air and water is essential. NPs recently gained considerable research attention as they help overcome the limitations of traditional treatments.

Recent studies show that inhalation and skin contact can prime the in human body. A significant challenge posed by nanotechnology is that the small particles produced can be inhaled or ingested, potentially creating medical and environmental risks. Substances that are generally non-toxic may become hazardous when inhaled as nanoparticles. The consequences of inhaled nanoparticles can include lung inflammation and cardiovascular issues. Additionally, metal nanoparticles can generate ros within cells. Nanoparticles can release ions into the surrounding environment, contributing to concerns regarding nanotoxicology. The NPs carcinogenicity primarily influenced due to structural characteristics, capping agents employed. NPs that are well-dispersed tend to be less toxic compared to those that are aggregated. They can be safe in lower doses, while higher doses present a toxic risk. To address the challenges associated with nanoparticles, system for monitor all effects of the synthesized nanoparticles (Golinska et al., 2014).

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