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Sustainable Pathways in Synthesis of Nanoparticle, From Chemical Routes to Green Photosynthesis by Coprecipitation Method

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Abstract: ***Nanoparticle synthesis remains a central concern in nanoscience due to the growing demand for materials with controlled size, shape, composition, and biocompatibility, particularly for medical and pharmaceutical applications. Conventional bottom-up and chemical approaches, such as co-precipitation and microemulsion techniques, offer reproducibility and uniformity but often involve high costs, toxic reagents, and environmental risks that limit their broader applicability. Advances in iron oxide nanoparticle synthesis have demonstrated improved control over crystallinity and particle size through temperature regulation and precursor selection, yet challenges related to surfactant residues and large-scale production persist. In response, biosynthetic and plant-mediated routes have gained attention as environmentally friendly alternatives, leveraging naturally occurring phytochemicals that act as reducing and stabilising agents. These green approaches reduce chemical toxicity while enhancing compatibility for biomedical use, although practical constraints such as cultivation effort, contamination, and harvesting complexity remain unresolved. Alongside these developments, interest in heterocyclic scaffolds highlights the parallel need for mild, efficient reaction protocols using accessible materials, reinforcing the shift toward sustainable and application-oriented nanomaterial design.***

Keywords: Nanoparticle Synthesis, Green Nanotechnology, Iron Oxide Nanoparticles, Photosynthesis, Biocompatible Materials

1.Description

The term "Nanoparticle synthesis" describes processes for producing nanoparticles. Nanoparticles can be produced by "bottom-up" processes, such as nucleating and growing particles from tiny molecular distributions in liquid or vapour phase, or they can be formed from bigger molecules. Functionalization by conjugation to bioactive compounds is another method of synthesis. Since the very beginning of the development of nanoscience, high-yield and low-cost nanomaterial synthesis has been a major difficulty. The ability to produce nanoparticles with various shapes, mono-dispersities, chemical compositions, and sizes is necessary for their use in medicine. Co-precipitation is a simple method for synthesising nanoparticles that can be made in a variety of sizes. The production of more uniformly sized nanoparticles has been achieved using several additional techniques. An iron supply and sodium hydroxide nanoemulsion are combined to form magnetite nanoparticles (NaOH). The surfactant is cleaned with ethanol after the nanoparticles have been removed using acetone lysis. Colloidal nanoparticles exhibit significant magnetism and super-paramagnetic characteristics. The dissolved compounds are present in the oil and water phases. In addition, the system's physicochemical characteristics play a significant role in the choice of surfactant material. This approach works with cationic, anionic, and non-ionic surfactants of any sort. The process of scaling up and the negative impacts of residual surfactants could pose some challenges for nanoparticles made using microemulsion techniques via a water/oil microemulsion. Chin and Yaacob (2007) demonstrated iron oxide NPs smaller than 10 nm, which are smaller than those produced by coprecipitation. Lee demonstrated in a different investigation that utilising an iron precursor at a high temperature led to the formation of crystalline maghemite nanoparticles. Sun (2004) also found that very tiny magnetite nanoparticles were created in the same way. RRJPN| Volume 10 | Issue 3|June, 2022 11 Research & Reviews: Journal of Pharmaceutics and Nanotechnology e-ISSN: 2347-7857 P-ISSN: 2347-7849 There are many ways to create nanoparticles, including physical, chemical, and biological processes. In general, physical and chemical approaches are thought to be the most effective for producing stable, uniform-sized nanoparticles. These methods, however, cost a fortune and let dangerous or harmful substances into the environment. Chemical processes that involve toxic chemicals for nanoparticle synthesis result in nanoparticles that are less acceptable for usage in food, cosmetics, or medicine. Enhancing the biocompatibility of nanoparticles is crucial because many of them have been widely used in medical applications, illness detection, and cosmetics. For the past ten years, biosynthetic methods have received a lot of attention in the quest to produce metal nanoparticles, including silver, gold, copper, and platinum. Because the stabilising and reducing agents utilised in biosynthetic nanoparticle synthesis are bacteria, fungi, yeasts, or plants themselves or their active components, these methods are thought to be environmentally beneficial. For the green production of different nanoparticles, multiple plant species and materials originating from plants have been discovered over the past ten years. Numerous plants include a variety of biologically active substances that function as reducing agents for metal salts, including alkaloids, phenols, flavonoids, ascorbic acid, citric acid, polyphenols, terpenes, and reductase. These phytosynthesis methods hold great promise because the plant components can function as capping and reducing agents. Synthesis of phytonanoparticles might occur via extracellular or intracellular processes. The chosen plant species can produce metallic nanoparticles within their cells when grown in organic media, soil, or hydroponic

solutions that are rich in metals. To culture, watch after, track, and harvest nanoparticles needs a lot of work. Additionally, using such techniques results in the adulteration of biomolecules, other components, plant pathogens, and tissues. Heterocyclic moieties are significant scaffolds that have both pharmacological and industrial applications. Various scientific groups have focused their attention on expanding simple reaction protocols by introducing better functional group compatibilities under mild reaction conditions, utilising easily available starting materials.

2.Conclusion

The evolving landscape of nanoparticle synthesis reflects a gradual but clear movement away from purely chemical-intensive methods toward more sustainable and biologically inspired approaches. While traditional physical and chemical techniques continue to provide control and reliability, their environmental and toxicological limitations restrict wider adoption, especially in sensitive fields such as medicine and cosmetics. Green synthesis using plant-based systems offers a promising balance between functionality and safety, supported by the natural reducing and capping abilities of phytochemicals. However, issues related to scalability, process control, and material purity indicate that no single method currently offers a complete solution. Continued refinement of hybrid strategies, combined with simplified reaction protocols and careful material selection, is likely to define future progress in nanoparticle development for both industrial and biomedical applications.

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