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# A Review On: Nanoparticle In Medicine

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***Abstract:*** One of the most revolutionary areas of contemporary pharmaceutical science is nanotechnology, which provides creative ways to get around the drawbacks of traditional drug delivery methods. Poor water solubility, instability, low bioavailability, quick metabolism, and limited absorption of numerous phytoconstituents are some of the difficulties faced by herbal medicine, despite its reputation for therapeutic efficacy, safety, and cultural acceptance. One potential solution to these issues is the use of nanotechnology in herbal preparations. The therapeutic efficacy of herbal medications can be greatly increased by encasing or delivering herbal actives through nanoparticles like polymeric nanoparticles, solid lipid nanoparticles (SLNs), nanostructured lipid carriers (NLCs), nanoemulsions, liposomes, metallic nanoparticles, and phytosomes. These nanosystems increase solubility, preserve bioactives from degradation, allow deep penetration into tissues, prolong systemic circulation, and provide controlled. Additionally, the “green synthesis” of nanoparticles can be made eco-friendly and biocompatible by using plant extracts as natural reducing and stabilising agents. The foundations, varieties, preparation processes, characterisation methods, benefits, difficulties, and wide range of therapeutic uses of nanoparticles in herbal medicine are the main topics of this review. By combining nanotechnology with traditional herbal knowledge, new treatment approaches that are safer, more effective, more scientifically advanced can be developed.

***Keywords*:** Herbal Nanomedicine, Nanoparticles, Herbal Nanoparticles, Nano-Drug Delivery Systems, Phytochemicals, Bioavailability Enhancement, Polymeric Nanoparticles, Lipid-Based Nanocarriers, Green Synthesis, Phytosomes

## I. INTRODUCTION

Using phytochemicals like flavonoids, alkaloids, terpenoids, phenolics, and glycosides, herbal therapy has been utilised for centuries in ancient systems including Ayurveda, Siddha, Unani, and ancient Chinese therapy. Many herbal compounds have serious drawbacks, including poor water solubility, large molecular size, low membrane permeability, quick first-pass metabolism, and instability in physiological settings, despite their tremendous therapeutic potential. These difficulties restrict their clinical application and significantly lower their therapeutic concentration at the target site. Advanced delivery platforms that can improve the pharmacokinetic and pharmacodynamic characteristics of herbal compounds without sacrificing their inherent safety profile are desperately needed as modern healthcare increasingly demands high-precision, evidence-based medicines.

One revolutionary way to get around these intrinsic drawbacks of herbal remedies is using nanotechnology. Materials have special physicochemical characteristics in the nanoscale (1–100 nm), including larger surface area, better solubility, higher reactivity, and stronger interactions with biological membranes. Polymeric nanoparticles, solid lipid nanoparticles, nanostructured lipid carriers, liposomes, metallic nanoparticles, nanoemulsions, and phytosomes are examples of nanoparticle-based herbal delivery systems that have shown notable improvements in phytoconstituent solubility, stability, absorption, and targeted delivery. These nanosystems facilitate controlled and sustained release, encourage deeper tissue penetration, and shield bioactive chemicals from enzyme breakdown and environmental instability. Therefore, as compared to their traditional extract forms, herbal nanoparticles exhibit greater therapeutic efficiency in situations like cancer, inflammation, microbial infections, metabolic disorders, and skin diseases.

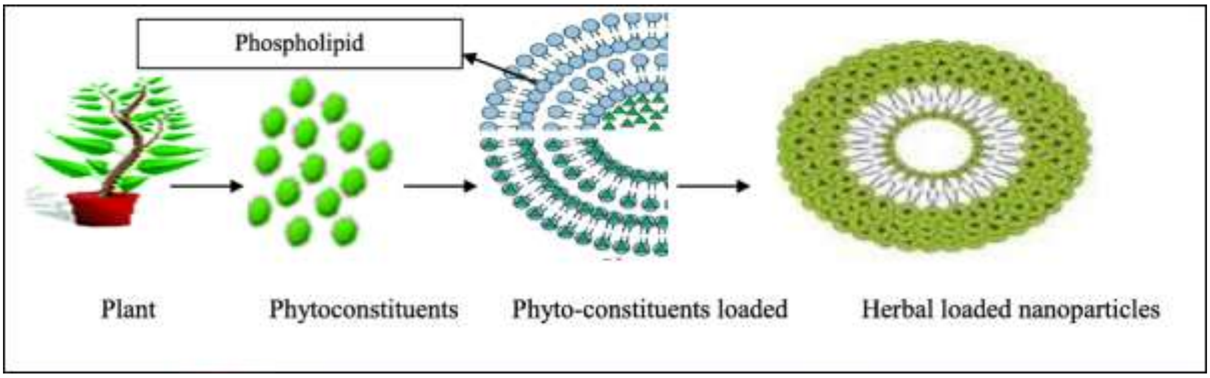


Fig. 1: PROCESS OF NANOPARTICLE

Nanotechnology not only improves bioavailability but also makes it possible for novel strategies including receptor-mediated uptake, site-specific targeting, and multifunctional drug delivery systems that integrate therapy and diagnostics (theranostics). The eco-friendliness, affordability, and inherent biocompatibility of green synthesis of nanoparticles utilising herbal extracts have drawn a lot of interest. This method eliminates the need for hazardous chemicals in the production of nanoparticles by using phytochemicals as natural reducing and stabilising agents. A significant development in contemporary phytopharmaceutical research is the integration of nanotechnology with herbal medicine, given the global trend towards safer, more effective, and sustainable medical treatments. Thus, researching herbal nanoparticles is essential to transforming conventional herbal remedies into therapeutic items that are clinically successful, scientifically proven, and commercially scalable.

The global shift from empirical traditional treatments to standardised, repeatable, and scientifically verified therapeutic systems is further supported by the integration of nanotechnology with herbal medicine. Due to variations in the plant source, extraction technique, and metabolite content, conventional herbal extracts frequently experience batch-to-batch variability and uneven clinical results. By providing accurate encapsulation, measurement, and regulated release of active phytoconstituents, nanoparticle-based administration helps solve these problems by lowering variability and enhancing therapeutic predictability. Additionally, co-delivery of several herbal actives in a single system is made possible by nanoscale carriers, which enhances the synergistic pharmacological effects frequently seen in conventional herbal formulae. Nano-herbal systems offer a cutting-edge platform that can satisfy worldwide pharmaceutical standards while maintaining the comprehensive advantages of plant-based therapy, as regulatory frameworks place an increasing emphasis on quality, safety, and efficacy.[1-5]

## II. CLASSIFICATION OF NANOPARTICLES

Both composition and structure can be used to classify nanoparticles. They are commonly categorised as (1) organic, (2) inorganic, and (3) carbon-based nanoparticles. Polymeric carriers (Nano spheres and Nano capsules), liposomes, dendrimers, micelles, and other biodegradable materials are examples of organic nanoparticles. Metal and metal-oxide particles (such as Ag, Au, and ZnO NPs), ceramic oxides, and semiconductors are examples of inorganic nanoparticles. Carbon nanotubes and fullerenes are examples of carbon-based nanomaterials with special strength and conductivity characteristics. Each class can also vary in form, surface chemistry, and size (0D spherical, 1D rods, etc.). Due to their biocompatibility, organic polymeric and lipid-based carriers are most frequently used in herbal medicine, whereas inorganic NPs—particularly green-synthesized silver or gold—are employed for imaging or antibacterial purposes.[6-7]

## III. PROPERTIES AND NEED OF NANOPARTICLES IN HERBAL SYSTEM:

Formulations for herbal nanoparticles take advantage of the special size-dependent characteristics of nanomaterials. In addition to having a high surface-area-to-volume ratio, nanoscale systems may have different optical, solubility, and reactivity characteristics. Importantly, the pharmacokinetics of plant actives are significantly improved by nanocarriers. For instance, phytochemicals that are unstable or weakly soluble in water can be successfully solubilised and shielded within nanoparticles. According to bibliometric research, herbal nanoparticles generally offer * "improved bioavailability, enhanced stability, and reduced toxicity" when compared to raw extracts. Moreover, tissue-specific distribution and retention can be improved by modifying the nanoparticle surface (e.g., with targeting ligands). All things considered, nanosizing herbal medications can increase the pace of solubility, stop premature metabolism, allow for controlled release, and facilitate the passage through biological barriers. Because of these benefits, using nanocarriers to convert classic medicines into contemporary therapies is appealing.[8]

## IV. TYPES OF HERBAL BASED NANOCARRIERS:

Different nanocarriers have been adapted for herbal drug delivery. Major types include:

1. POLYMERIC NANOPARTICLES:

Solid colloids made of biodegradable polymers, such as chitosan and PLA/PLGA, are known as polymeric nanoparticles. Drugs may adhere to the surface of a polymer matrix or become trapped within it. Large drug loads can be carried by polymeric NPs, which are typically 50–1000 nm in size and can shield delicate phytomolecules. The polymer shell can be modified for targeting or for controlled release using PEGylation or antibodies. For instance, PLGA nanoparticles coated with curcumin have demonstrated increased anticancer efficacy and prolonged release.

2. SOLID LIPID NANOPARTICLE:

These are lipid-based vesicles composed of solid lipids at body temperature or room temperature. While NLCs contain both solid and liquid lipids, SLNs (80–1000 nm) are made up of a single solid lipid matrix (such as triglycerides or waxes). They offer good biocompatibility, the capacity to load lipophilic herbal actives, and protection against degradation by combining the benefits of polymeric NPs and liposomes. SLNs are capable of transdermal medication delivery by penetrating the stratum corneum. For example, SLNs infused with curcumin have been designed to improve skin absorption and reduce inflammation.

3. LIPOSOMES:

Spherical vesicles with an aqueous core surrounded by one or more phospholipid bilayers. Both hydrophilic (in the core) and hydrophobic (in the membrane) herbal actives can be encapsulated in liposomes, which are well-known medication carriers. They resemble biological membranes and are biocompatible and biodegradable. Liposomes provide tailored delivery and improve the stability of delicate substances (e.g. by attaching ligands). Herbal liposomes have been shown in numerous investigations to improve circulation time and absorption in tumour cells or macrophages. For instance, compared to free curcumin, liposomal curcumin has superior stability and bioactivity.

4. NANOEMULSION:

Emulsions of water and oil with droplet sizes ranging from 20 to 500 nm. They are surfactant-stabilized dispersions that are kinetically stable but thermodynamically unstable. By solubilising hydrophobic herbal components in oil droplets, nanoemulsions can significantly increase bioavailability. Additionally, they can be administered orally, transdermally, nasally, and in a variety of dose forms, including gels, sprays, and injectables. Turmeric oil that has been nanoemulsified, for example, has demonstrated enhanced anti-inflammatory properties.

5. METALLIC NANOPARTICLES:

NPs made of metal or metal-oxide (such as ZnO, iron oxide, silver, or gold). These inorganic NPs can be produced utilising green plant-based techniques (using herbal extracts as reducing/stabilizing agents) or traditionally (chemical reduction). Metallic nanoparticles (NPs) frequently possess intrinsic bioactivity. For example, silver NPs have broad-spectrum antibacterial activity due to their vast surface area, and gold NPs can be used in photothermal cancer therapy when combined with plant chemicals. Although metallic nanoparticles

(NPs) have special diagnostic and therapeutic uses in herbal nanomedicine, care must be taken due to their toxicity.

6. DENDRIMERS:

Polymeric macromolecules having several surface functional groups and a central core that are very branched and resemble trees. Internal cavities for drug encapsulation can be created by accurately synthesising dendrimers, which are typically 1–10 nm in size, in generations. Targeting ligands or many medication molecules can connect to their multivalent surfaces. Flavonoids and anti-cancer phytochemicals have been transported using dendrimers for herbal delivery, enhancing cellular absorption and prolonged release.

7. PHYTOSOMES:

A unique kind of lipid–phospholipid complexes in which phospholipids are chemically linked to bioactive phytochemicals, such as flavonoids. Phytosomes are molecular complexes rather than vesicles that significantly increase the herbal compound's absorption. For instance, compared to free curcumin, curcumin–phosphatidylcholine phytosomes have greater plasma levels and superior therapeutic effects. Phytosomes combine improved plant extract distribution with the biocompatibility of lipids.[9-14]

## V. MECHANISM OF HERBAL NANOPARTICLE ACTION:

Through a number of interrelated biological and physicochemical processes, herbal nanoparticles improve the therapeutic efficacy of plant-based medicines. Because of the large increase in surface area at the nanoscale, the solubility and dissolution rate of herbal extracts or phytochemicals greatly increase when they are transformed into nanoparticles. This boosts absorption through the gastrointestinal system and increases their capacity to dissolve in physiological fluids. Additionally, by shielding herbal ingredients from oxidation, light, stomach acidity, and enzymes, nanoparticles enable the active molecules to enter the systemic circulation in a stable form. Because of their small size, they can effectively traverse biological membranes through endocytosis, transcellular transport, or passive diffusion, increasing the intracellular concentration of the herbal medication.

Herbal nanoparticles also provide phytochemicals in a targeted and long-lasting manner. Nanoparticles tend to concentrate more in diseased tissues, such as tumours or inflammatory areas, where lymphatic drainage is poor and blood vessels are leaky, due to the Enhanced Permeation and Retention (EPR) effect. This passive targeting reduces exposure to healthy tissues while increasing the local concentration of herbal active ingredients at the site of action. [16-17]


Fig.2 MOA OF HERBAL NAANOPARTICLE

## VI. PREPERATION METHODS:

I. Method of Nanoprecipitation (Solvent Displacement Method)

- One of the most straightforward and popular methods for creating polymeric herbal nanoparticles is this one.
- This approach involves dissolving the phytochemical or herbal extract with a polymer in an organic solvent (such as ethanol or acetone).
- Then, while stirring continuously, this organic phase is gradually introduced to an aqueous phase that contains a stabiliser.
- As the solvent diffuses into water, nanoparticles naturally develop due to the difference in solubility between the two phases.
- The solvent evaporates to gather the finished nanoparticles.

II. Method of Solvent Evaporation

- Hydrophobic herbal substances are the primary application for this technique.
- A polymer and a volatile organic solvent, such as dichloromethane, are used to dissolve the herbal medication.
- An oil-in-water emulsion is created by emulsifying this solution with water.
- Solid nanoparticles are left behind after the organic solvent evaporates due to constant stirring.
- After that, these nanoparticles are cleaned and centrifuged.

III. Homogenisation at High Pressure

- Lipid nanoparticles (SLNs, NLCs) are frequently prepared using this technique.
- Under extremely high pressure (500–1500 bar), a hot lipid phase containing the herbal extract is pushed through a small opening.
- The lipid droplets are broken up into nanometer-sized particles by the extreme shear stress.
- The lipid forms into stable herbal nanoparticles after cooling

IV. Method of Ultrasonication

- Larger droplets are broken up into nanoparticles by ultrasonic vibrations.
- A lipid or polymer phase is combined with herbal extract.
- Droplet size is decreased by high-frequency waves produced by a probe sonicator. Nanoemulsions or nanodispersions are produced by the method.

V. Green Synthesis (Plant-Mediated Nanoparticle Formation)

- This technique creates metallic nanoparticles by reducing metal ions (such as $Ag^+$ and $Au^{3+}$) using plant extracts.
- Water is used to remove plant seeds, roots, or leaves. The metal salt solution is supplemented with this extract.
- Alkaloids, terpenoids, and flavonoids are examples of phytochemicals that function as organic stabilising and reducing agents.
- Metal nanoparticles are created without the use of hazardous chemicals in a matter of minutes to hours.[18-22]

## VII. ADVANTAGES

By improving the solubility, stability, and bioavailability of phytochemicals that are poorly soluble in water, herbal nanoparticles provide important benefits. Their increased surface area due to their nanoscale size allows for better absorption via biological membranes and quicker disintegration. By shielding delicate herbal chemicals from oxidation, light, stomach acid, and enzymes, nano-encapsulation extends their circulation duration. Through processes like the Enhanced Permeation and Retention (EPR) effect or ligand-mediated binding, these nanosystems also allow targeted delivery to certain tissues, increasing therapeutic concentration at sick locations while lowering side effects. Herbal nanoparticles also offer continuous and regulated release, guaranteeing steady plasma levels and lowering the frequency of dose. All things considered, these benefits make herbal nanoparticles much more dependable, safe, and effective than traditional herbal formulations.[23-25]

## VIII. LIMITATIONS

Despite their therapeutic advantages, herbal nanoparticles also face several limitations that affect their development and practical use. One major challenge is the variability of herbal extracts, as differences in plant source, extraction method, and phytochemical composition can lead to inconsistent nanoparticle quality and reproducibility. Many preparation techniques require specialized equipment, high energy input, or organic solvents, which may increase production cost and complexity. Stability issues such as particle aggregation, changes in size, or degradation during storage can also reduce the effectiveness of nanoformulations. Additionally, large-scale manufacturing of herbal nanoparticles remains difficult due to challenges in maintaining uniform particle size and entrapment efficiency. Regulatory approval is another limitation, as there are no clear global guidelines for evaluating the safety, toxicity, and quality of nano-herbal products. Furthermore, long-term toxicity, biodistribution, and environmental impact of nanoparticles are not fully understood, creating concerns regarding their clinical translation.[26]

## IX. APPLICATION

Herbal actives have been used to apply nanoparticles to a variety of therapeutic areas:

Anti-cancer. Nano carriers enhance the transport of poorly soluble phytochemicals to tumours, such as bebeerine, curcumin, and paclitaxel analogues. For example, curcumin–gold nanoparticle conjugates have been employed in combined photo thermal-chemotherapy: the associated curcumin is released intracellularly to cause apoptosis, while the gold NPs target the tumour and produce heat under laser irradiation, killing cancer cells. According to numerous studies, Nano formulated herbal substances exhibit less systemic toxicity and more cytotoxicity against cancer cells when compared to free drugs.

Anti-inflammatory/Antioxidant: Nano-herbals have been used to treat inflammatory conditions like colitis and arthritis. The stability and tissue retention of anti-inflammatory extracts (such as ginger, turmeric, and Boswellia) are improved when they are encapsulated in liposomes or polymeric nanoparticles. Chronic inflammation can be more successfully controlled by the prolonged release of antioxidants from nanoparticles. For instance, in animal models, liposomal curcumin has demonstrated enhanced reduction of inflammatory markers.

Antibacterial: Herbal extracts' antibacterial qualities are enhanced by nanoparticles. Particularly potent bactericidal effects are exhibited by silver nanoparticles, which combine the metal's activity with phytochemical antibacterials when stabilised with plant extracts. Polymeric NPs or nanoemulsions containing essential oils (such as clove, tea tree, etc.) show increased potency and permeability into bacterial biofilms. These herbal nanoantibiotics are being investigated for use against diseases that are resistant to drugs.[27-29]

## X. FUTURE SCOPE

Herbal nanoparticles are currently mostly in the research stage despite numerous encouraging findings. Regulations, long-term safety, and large-scale manufacturing must be addressed in future work. To confirm that nano-encapsulated botanicals are safer and more effective in humans, more in vivo and clinical research is required. In terms of technology, next-generation carriers are being developed: biomimetic (cell-membrane-coated) NPs, stimuli-responsive nanogels, and plant-derived exosome-like nanoparticles may provide even greater targeting and biocompatibility. Formulations will become more sustainable because to developments in green nanotechnology (completely bio-based carriers and synthesis). Lastly, integrating nanosystems with bioinformatics/AI and personalised medicine (creating carriers for a patient's particular pathology) could maximise treatment. In the future, herbal nanomedicine may provide safer, more accurate, and more efficacious phytotherapies thanks to these developments.[30]

## XI. CONCLUSION

The full potential of herbal therapy could be unlocked with the help of nanoparticle delivery technologies. Nanocarriers can greatly improve therapeutic results by enhancing the solubility, stability, and targeting of medications generated from plants. The manufacture, characterisation, and modes of action of the main nanoparticle types employed in herbal drug delivery—polymeric, lipid-based, metallic, dendrimers, phytosomes, etc.—have been reviewed. The benefits are evident: targeted and regulated delivery of herbal actives can result in greater efficacy and fewer adverse effects, even though safety and scale-up issues still exist. Novel nanophytomedicines that incorporate traditional herbal remedies into contemporary clinical practice are anticipated to result from ongoing research and development in this area.

## XII. ACKNOWLEDGEMENT

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## XIII. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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