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Bridging the Gap: The Convergence of Traditional Medicinal Wisdom and Modern Nanotechnology in Healthcare

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Abstract

Today, old-fashioned herbal medicines and new science findings are being used together to change the way people all over the world get medical care. Natural goods have been the main source of health care for 80% to 85% of the world's people for many generations. These natural, plant drugs are important in many places, but we need to focus again on making them better in terms of quality, effectiveness, and safety. In this century, biogenic phytonanoparticles have become a new way to treat diseases. This is in line with the goals of protecting the environment and making scientific progress. A lot of different metal nanoparticles can be made with green chemistry methods. These include copper, silver, iron, zinc, and titanium oxide. These nanoparticles are cheap, safe, and last a long time. New nanomaterials with unique physical, chemical, and biological features can be made using processes that are controlled by plants. This opens the door to new medicinal uses like antioxidants and anti-aging medicines. Natural goods can now be made faster in a lab thanks to new technologies. This is a faster way to get them than the old ways. The rise of healthcare has reached a new level as cutting-edge science methods are used along with traditional medical knowledge. Based on morals and current technology, this review shows how biogenic phytonanoparticles could lead to new study and treatment choices. Putting sustainability and new ideas together is a big step forward that leads to exciting new ways to make people healthier. Making metallic nanoparticles is also a very important area of study that is still going on. This is because it could lead to better and more personalized uses for these materials in health, catalysis, and electronics. To get the most out of metals nanoparticles and move science and business forward, this study is very important.

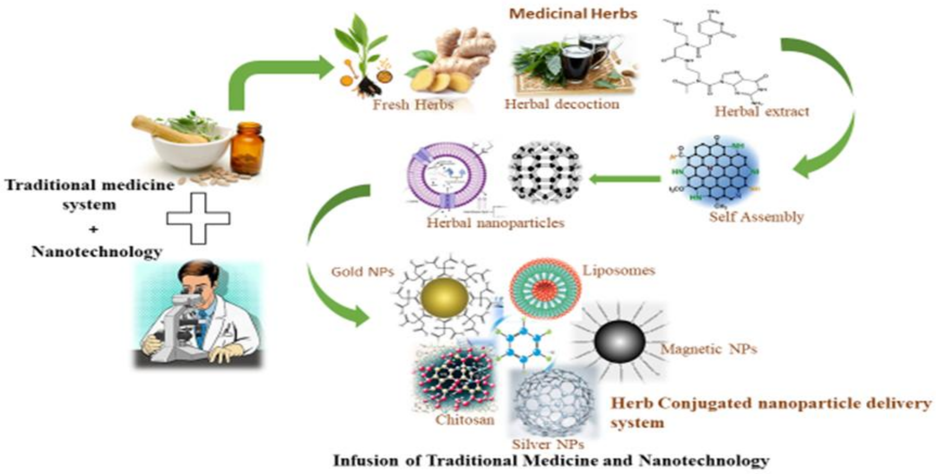

Figure 1: Graphical abstract

Keywords: Traditional Medicine, Nanoparticles, Modern Pharmaceutical, Phytochemicals.

INTRODUCTION

In many cultures across the globe, plants have played a significant role in traditional medicine for thousands of years. Early human cultures discovered a variety of plants with medicinal qualities via observation and experience; this body of knowledge grew over the course of generations.

Many contemporary medications, such as those for cancer, heart disease, and infections, are derived from plants. Aspirin, a popular pain reliever derived from willow tree bark, is a well-known example. This demonstrates the continued significance of plant-based chemicals in medicine [1]. A new field of study called "Green Synthesis Approaches for Developing Plant-Based Nanoparticles in Phytopharmaceuticals" uses cutting-edge nanotechnology in conjunction with eco-friendly techniques to harness the therapeutic potential of plants. This process creates nanoparticles in an eco-friendly manner by using plant extracts. Compared to conventional chemical treatments, it is a safer and superior solution [2]. Silver nanoparticles (AgNPs), which are generated from plants, have attracted attention due to their potential to increase the efficacy of phytopharmaceuticals, especially in antibacterial, anticancer, and anti-inflammatory treatments. The natural reducing agents, phytochemicals, and antioxidants found in plants are used in the green production of nanoparticles. Because of this, the procedure is safe for both the environment and living beings. This method has the potential to produce novel plant-based medications with fewer adverse effects, which will support the development of phytopharmaceuticals in contemporary medicine [3].

The development of nanotechnology in the twenty-first century has facilitated the creation and characterization of several novel materials. Herbal medicine, also known as botanical medicine or phytotherapy, treats patients by using plant components such as leaves, roots, and flowers. Historically, indigenous and tribal cultures across the world have used phytotherapeutic treatments, tailoring their medical practices to their own environmental and cultural conditions [4]. Depending on where they live, these groups usually exhibit a variety of social, cultural, and economic activities. For instance, 8.6% of Indians are members of tribal communities, which contributes to the preservation and use of traditional medical knowledge [5]. Indigenous communities have accumulated a wealth of knowledge on the use of plants as medicine. Southeast Asian traditional healers, for instance, use about 6,500 distinct plant species. This extensive ethnobotanical knowledge has greatly aided the current pharmaceutical industry's research and documentation. By producing silver nanoparticles (AgNPs) in an environmentally friendly manner, several of these plants' inherent antibacterial qualities may be strengthened [6].

These plants also hold great promise for the production of antibacterial and anticancer medications. They are excellent candidates for novel medical therapies since they often have fewer or no adverse effects. For many of their everyday necessities, including food, medicine, and construction materials, indigenous and tribal cultures rely on forest resources. These woods are crucial because they preserve their cultural traditions while providing food, shelter, and medical treatment. These communities' intimate relationships to their surroundings have resulted in sustainable methods of using plant-based resources, which are essential to their well-being and survival [7]. Tribal people have traditionally utilized *Rauwolfia serpentina* to cure snakebites because it contains reserpine, an active component that is now often used in modern medicine to treat high blood pressure. Long used to reduce fevers, *Artemisia annua* is also the source of artemisinin, a potent medication used to treat malaria. These instances demonstrate the significance of traditional plant knowledge in the development of life-saving contemporary medications. Innovative methods that enable accurate observation, measurement, manipulation, and control of materials at the nanoscale enable both theoretical and practical improvements in nanotechnology. Through the integration of nanostructures and nanophases in a variety of domains, nanotechnology has effectively bridged the gap between the biological and physical sciences. Fields like nanomedicine and nano-based drug delivery systems have been significantly impacted by this integration, creating new avenues for treatment innovation and improvement [8].

The use of nanoscale materials for targeted medication delivery and diagnostic applications has significantly enhanced nanomedicine. According to [9], nanotechnology has shown to be very beneficial in the fields of targeted medicines, gene therapy, regenerative medicine, cancer, and disease diagnosis and treatment. Nanoscale advancements have produced technologies and materials with special qualities that set them apart from their larger-scale equivalents. "Biogenic" refers to the process of breaking down dissolved metals into nanoparticles utilizing plant or cell extracts. Biogenic nanoparticles are renowned for their enhanced stability and great polydispersity, which allows them to exist in a variety of sizes. Nanoparticles may be created primarily in three ways: chemically, biologically, and physically. However, physical and chemical procedures are frequently expensive and time-consuming. However, since biological approaches do not need severe processing stages, they may be produced under gentle settings such as physiological pH, temperature, and pressure, making them a more economical way to create nanoparticles [10]. Because conventional technologies have negative environmental implications, researchers are searching for environmentally acceptable alternatives to create nanomaterials. Green synthesis techniques are gaining popularity because they produce nanomaterials in a more environmentally friendly and safe manner. Numerous biomolecules found in plants aid in the reduction of metal ions. Alkaloids, flavonoids, aldehydes, phenolics, ketones, polysaccharides, saponins, tannins, and terpenoids are a few of these. The reduction process often involves many molecules from these categories. By acting as both capping and reducing agents, these phytomolecules help create nanoparticles from metal salt precursors and enhance their stability and production [11].

The transformation of metal salt precursors into nanoparticles (NPs) is often indicated by a discernible color shift in the colloidal solution. Phytonanoparticles (PNPs) may be produced in three primary ways: (i) extracellular synthesis, which employs plant extracts; (ii) intracellular synthesis, which forms nanoparticles within plant tissues; and (iii) individual synthesis, which utilizes certain phytochemicals to aid in the formation of nanoparticles. The natural biomolecules found in plants play a crucial role in each technique by reducing metal ions and maintaining the stability of the nanoparticles. There are typically three primary processes involved in the bio-reduction of metal nanoparticles using plant extracts. The nucleation process starts with the reduction of metal ions, which is known as activation. The next stage is growth. The nanoparticles assemble and enlarge throughout this period, increasing their thermodynamic stability. The nanoparticles finally acquire their final, distinct form during the termination phase. At every step, it's critical to achieve the ideal nanoparticle size, shape, and stability [12]. Silver, gold, zinc, selenium, and platinum are among the noble metal nanoparticles that show significant scientific promise for the detection and treatment of serious illnesses including Parkinson's disease, HIV, cancer, and TB. Platinum nanoparticles are used in bone allografts and dentistry, gold nanoparticles are effective in transporting medications, and silver nanoparticles are well-known for their novel antibacterial qualities. However, the toxicity of these nanoparticles continues to worry people. These safety concerns must be addressed, and efforts are ongoing to enhance biocompatibility and reduce adverse effects [13]. The exciting possibility of combining antibiotics with metallic nanoparticles to maintain bacterial resistance to these drugs is highlighted by recent studies. This approach of treating bacterial infections is novel and practical. Even against bacteria that are resistant to several medications, metallic nanoparticles may improve the effectiveness of standard medicines. Using the special qualities of nanoparticles, this combined therapy may be a significant advancement in the treatment of bacterial infections that don't improve with existing therapies [10]. The sustainable method of producing silver nanoparticles (AgNPs) from waste and biological sources

Materials that adhere to green chemistry principles are ecologically sustainable and economically viable. This technique produces biocompatible nanoparticles applicable in antibacterial, antifungal, antiviral, and anticancer therapies. Furthermore, AgNPs function as natural catalysts for pollutant degradation, aid in the management of diabetes-related problems, and enhance wound healing, rendering them very adaptable in several medicinal and environmental applications [14].

Phytonanoparticles (PNPs)

Plant-based phenylanoparticles (PNPs) are now a durable substitute for conventional physical and chemical nanoparticle production techniques.

A one-step biosynthesis process is made possible by the green synthesis technique, which employs plants and is growing in popularity due to its speed, affordability, and environmental safety. Phytoconstituents such as steroids, saponins, polysaccharides, and flavonoids are crucial for reducing metal ions, and plants act as natural reducing agents in this process. To further ensure the stability of nanoparticles throughout the manufacturing process, a variety of chemicals originating from plants are used as capping agents [15]. On the other hand, the hazardous reducing, capping, and stabilizing compounds used in conventional chemical processes for creating nanoparticles may be costly and harmful to the environment. Because it utilizes less energy and fewer hazardous chemicals, the green synthesis approach is more economical and environmentally friendly than other methods for producing nanoparticles [16]. Because of its potential uses in a variety of fields, such as environmental cleanup, agriculture, and medicine, phytonanoparticles are now garnering a lot of attention. Important physical and chemical characteristics of certain plants enable the environmentally friendly production of nanoparticles. Phytoconstituents facilitate the regulated assembly of nanoparticles. Phytonanoparticles (PNPs) have unique features that make them valuable in a variety of industries due to their plant-mediated production process [17].

Phytonanoparticles (PNPs) increase medication efficacy and decrease adverse effects by delivering tailored, site-specific activities. Their methods of operation enable them to evade immunological reactions and pass-through cellular barriers that are difficult to penetrate. They are particularly effective in combating cancer because of this. In [18] Numerous nanotherapeutics have been developed in recent decades to treat a range of illnesses and conditions. Because PNPs are more effective at treating diseases, have minimal toxicity, and are biocompatible, they have become a potential choice [19].

• Greater Surface Area to Volume Ratio: PNPs' much greater surface area compared to volume facilitates their interaction with biological targets, increasing the efficacy of therapy [20].
• Improved Solubility and Bioavailability: PNPs improve the body's absorption of medications that don't dissolve well in water, increasing the bioavailability of the active ingredients [21].
• Improved Uptake by the Reticuloendothelial System (RES)-A vital part of the immune system, the RES efficiently recognizes and absorbs PNPs, allowing for more accurate targeting of pathogens or abnormal cells [22].
• Improved Absorption, Retention, and Permeability: These nanoparticles are designed to more readily pass through biological barriers, improving absorption and retention in target tissues and resulting in longer-lasting therapeutic benefits [23].
• Improved Stability of Drug Formulations: PNPs improve the physical and chemical stability of medications, ensuring that the medicinal ingredients remain intact and functional during usage and storage [24].
• Protection from Early Degradation: PNPs *in vivo* prevent medications from degrading before they reach their intended location, improving therapy outcomes [10].
• Targeted Delivery to Minimize Side Effects: PNPs have the ability to deliver medications straight to diseased cells, minimizing the possibility that they would impact healthy cells. According to [25], this focused strategy increases the drug's therapeutic index and significantly reduces the likelihood of negative side effects.

Plant-Based Nanoparticles for Biomedical Applications:

Advancements and Potential

Plant-based nanoparticles in biomedical applications is a new field of study that uses plant extracts to create nanomaterials in a more environmentally friendly manner. Plant-derived nanoparticles, also known as phytonanoparticles (PNPs), have many advantages, including being safe for living things, inexpensive, and good for the environment. Because plants contain a wide variety of bioactive compounds, they have a lot of potential for use in medicine and diagnosis, including drug delivery, antimicrobial therapies, cancer treatment, and tissue engineering, among other uses.

Advancements in Plant-Based Nanoparticles for Drug Delivery

Drug delivery is one of the most intriguing applications for plant-based nanoparticles. Drug delivery to certain cells or tissues is made feasible by nanoparticles, which also increase the solubility, stability, and bioavailability of medications. Plant-based nanoparticles have been investigated by researchers as a means of delivering a variety of medications, including proteins, nucleic acids, and tiny compounds. For example, it has been shown that gold nanoparticles (AuNPs) derived from *Azadirachta indica* (neem) leaf extract efficiently carry anti-cancer medications to target cells with fewer adverse effects [26]. Similarly, because of their antibacterial properties and ability to carry therapeutic compounds, silver nanoparticles (AgNPs) made from extracts of *Taxus wallichiana* show a great deal of promise in drug delivery systems [27]. The ability of these nanoparticles to bypass biological barriers increases the effectiveness of medication delivery to diseased tissues, particularly in the treatment of cancer and antimicrobials [28].

Plant-derived nanoparticles have significant potential for the treatment of cancer and infections due to their ability to disrupt bacterial cell membranes and induce oxidative stress in cancerous cells. A multitude of researchers is investigating silver nanoparticles due to its efficacy in eradicating germs, fungus, and viruses. They are effective against both Gram-positive and Gram-negative bacteria. Silver nanoparticles derived from Aloe vera extracts have shown significant efficacy against bacteria, suggesting their potential use in wound healing and infection prevention [41]. Plant-derived nanoparticles have considerable promise in cancer therapy by enhancing the effectiveness of chemotherapeutic drugs and reducing systemic toxicity. Nanoparticles derived from Curcuma longa extracts and encapsulating curcumin have shown enhanced bioavailability and improved efficacy in eradicating cancer cells [42]. These nanoparticles may facilitate targeted cancer therapy by delivering medications directly to tumor cells, therefore minimizing harm to healthy organs.

Potential in Tissue Engineering and Regenerative Medicine

In addition to their use in medication delivery and antibacterial treatments, plant-based nanoparticles are gaining a lot of interest in tissue engineering and regenerative medicine. Scaffolds may have nanoparticles added to them to aid in tissue growth, modification, and repair. Plant polysaccharide-derived chitosan nanoparticles have been successfully used to promote wound healing and stem cell proliferation [43]. These plant-based nanomaterials are excellent for use in regenerative medicine since they are non-toxic and biocompatible.

Mechanisms of Action in Biomedical Applications

The effectiveness of plant-based nanoparticles in biomedical applications can be attributed to several mechanisms of action:
• Increased Bioavailability: Therapeutic chemicals are more soluble and durable when they are in nanoparticle form, which facilitates their entry and better distribution throughout the body [10].
• Targeted Delivery: By modifying nanoparticles with ligands that bind to specific receptors on diseased cells, medicinal drugs may be delivered to those cells directly, reducing the possibility of adverse effects [44].
• Antioxidant Activity: Because of the phytochemicals used in their synthesis, many plant-derived nanoparticles have inherent antioxidant properties that may reduce oxidative stress in illnesses including cancer and heart disease [45].
• Controlled Release: To ensure that the therapeutic benefits continue, plant-based nanoparticles may be engineered to release medications or bioactive chemicals gradually [46].

Advantages of Phytonanoparticles in Therapeutic Applications

Phytonanoparticles (PNPs) derived from plant extracts offer numerous advantages in medical applications. They are suitable for medical applications due to their biocompatibility and biodegradability. PNPs enhance drug delivery systems by increasing the surface area to volume ratio, thereby improving their interaction with biological systems. Silver nanoparticles synthesized from Aloe vera demonstrate significant efficacy against various pathogens [47].

Furthermore, PNPs can modify the release rate of drugs, thereby enhancing the pharmacokinetics of therapeutic agents. These nanoparticles enhance the stability of the drugs they encapsulate by incorporating natural phytochemicals in the synthesis process. This indicates that treatment plans may exhibit increased efficacy [48]. The ability to optimize drug delivery and improve therapeutic efficacy positions phytonanoparticles as a transformative approach in modern medicine.

Role of Phytonanoparticles in Drug Delivery Systems

Because phytonanoparticles are stable, biocompatible, and can be produced in environmentally friendly ways, their use in drug delivery systems has drawn a lot of interest. These plant extract-derived nanoparticles are excellent in delivering therapeutic chemicals to particular bodily locations, increasing the efficacy and safety of several therapies.

Mechanisms of Drug Delivery Using Phytonanoparticles

Phytonanoparticles' ability to encapsulate or bind therapeutic compounds, enabling controlled and targeted release, is what makes them effective in medication delivery. This may have a significant impact on how medications are absorbed, transported, metabolized, and eliminated from the body. Phytonanoparticles may contain pharmaceuticals in their core or be conjugated with medications, depending on how the drugs are to be delivered. PNPs may be used for a variety of drug delivery methods, including active and passive targeting. The increased permeability and retention (EPR) effect, which is often seen in tumor tissues, is used in passive targeting to help nanoparticles accumulate in these areas [49].

Conversely, active targeting entails incorporating ligands onto the surface of PNPs that attach to certain target cell receptors. This enhances the therapeutic outcomes by facilitating the cells' absorption of PNPs [50].

Traditional Medicinal Practices and Their Relevance Today

In many countries around the world, traditional medicine, especially those that are based on local information, has been an important part of health care. Since the Middle Ages, people have used medicines made from plants to treat a wide range of illnesses. These techniques are becoming more and more known in modern medicine, especially when it comes to finding and making new drugs. About 80% of people in the world still get most of their medical care from traditional medicine, according to the World Health Organization.

A lot of the time, traditional doctors know a lot about the plants that grow in their area and how to use them to heal. Because of this information, many plant types that might have medical uses have been found. In the past, *Rauwolfia serpentina* was used to treat snakebites. In modern medicine, reserpine, a powerful chemical from the plant, is now used to treat high blood pressure. This shows how traditional knowledge has worked its way into the field.

Future Perspectives on Traditional Medicine and Nanotechnology

Nanotechnology and standard medicine will work together in the future to improve health care. Scientists are still looking into how phytonanoparticles can be used as medicine, so it is important for academics and traditional doctors to work together. Together, they can help find interesting plant species and the useful chemicals that are found in them. These can then be used to make new drugs. Still, there are issues to be resolved, like the need for strict scientific proof of traditional knowledge and the need to make the process of creating nanoparticles more consistent. But the fact that integrative medicine models are becoming more popular shows that combining old methods with new technology to improve health results is on the way to a bright future.

DISCUSSION

Integration of Traditional Knowledge with Modern Science

Creating and using phytonanoparticles (PNPs) is a great example of how traditional plant treatment and modern nanotechnology are coming together. Traditional medical practices, which often use plant materials for their healing properties, provide a wealth of information that can greatly improve and expand current scientific study. The review stresses how important traditional knowledge is for finding out and confirming the healing qualities of different plant types. Reserpine from *Rauwolfia serpentina* and artemisinin from Artemisia annua are two examples of plants that have gone from being used in traditional ways to being used in modern medicine. This change shows how important it is to keep studying the many ways that plants and their useful parts can be used that haven't been looked into yet.

Phytonanoparticles: Synthesis and Characterization

Green chemistry and the other ways to make PNPs show that biogenic nanoparticles can be made in a way that is good for the world. The natural proteins found in plants are used in techniques like intracellular, external, and individual synthesis to make stable and bioavailable nanoparticles. What the review says is that phytoconstituents like flavonoids, saponins, and terpenoids help make nanoparticles smaller and more stable, which makes them better for medical use.

The results show that PNPs made from different plant products have better antibacterial and anticancer qualities. This is in line with how these plants have been used in the past to treat infections and other illnesses. The amazing ability of these nanoparticles to target specific cells and avoid defensive reactions is especially impressive because it makes plant drugs work better.

Therapeutic Applications and Efficacy

The review shows that PNPs can be used in medicine in a lot of different ways, mainly in places where drugs are delivered. Putting bioactive chemicals inside nanoparticles makes their metabolism much better. This makes treatments more specific and successful. It's clear from the talk that PNPs not only make hydrophobic drugs more stable and soluble, but they also make it easier to control how they're released, which makes therapy work better. For example, the fact that curcumin is more bioavailable when it is mixed with nanoparticles shows how traditional chemicals can be changed to avoid problems that come with their original forms. The fact that PNPs might make anti-cancer treatments better through specific delivery systems shows how useful it could be to combine old knowledge with new nanotechnology.

Challenges and Future Directions

Despite the encouraging findings, a few issues must be resolved before PNPs may be effectively used in clinical settings. Issues that need to be addressed include standardizing synthesis techniques, ensuring that traditional claims are supported by solid scientific data, and facilitating the use of herbal formulations. Furthermore, further study is required to determine the specific phytochemicals used in the manufacturing of nanoparticles and how they work.

Table 1: Some plants derived nanoparticles and their biological applications in human life

S. No.	Plants	Nanoparticles	Biological Applications	References
1	*Azadiricta indica*	Ag, Zno	Antimicrobial, anti-dengue	[29]
2	*Acalypha indica*	Ag, Au, Cu	Antibacterial, Anti-cancer, Antifungal	[30]
3	*Carica papaya L*	Ag, Zno	Antimicrobial, Bactericidal, Photocatalytic, Anti-cancer	[31]
4	*Cocos nucifera*	Ag	Antibacterial	[32]
5	*Boswellia serrata*	Au	Anti-acute myeloid leukemia	[33]
7	*Camellia sinensis L.*	ZnO	Antimicrobial	[34]
8	*Cassia auriculata*	ZnO, Ag	Antimicrobial, Anticancer, Catalytic	[35]
9	*Mentha piperita* (peppermint)	Ag	Antimicrobial, Antibacterial, Antifungal, Acetylcholinesterase	[36]
10	*Melia azedarach*	Ag, ZnO	Antidiabetic, Antioxidant, Antimalarial, Antibacterial	[37]
11	*Tinospora cordifolia*	Cu, Ag, Se	Antimicrobial, Larvicidal, Antibacterial, Antioxidant	[38]
12	*Trachyspermum ammi*	Ag	Antimicrobial, Antibacterial, Anti-oxidant, Anti-rheumatic	[39]
13	*Vitex negundo L.*	Ag, Au	Antimicrobial, Anticancer, Antibacterial, Nephroprotective	[40]

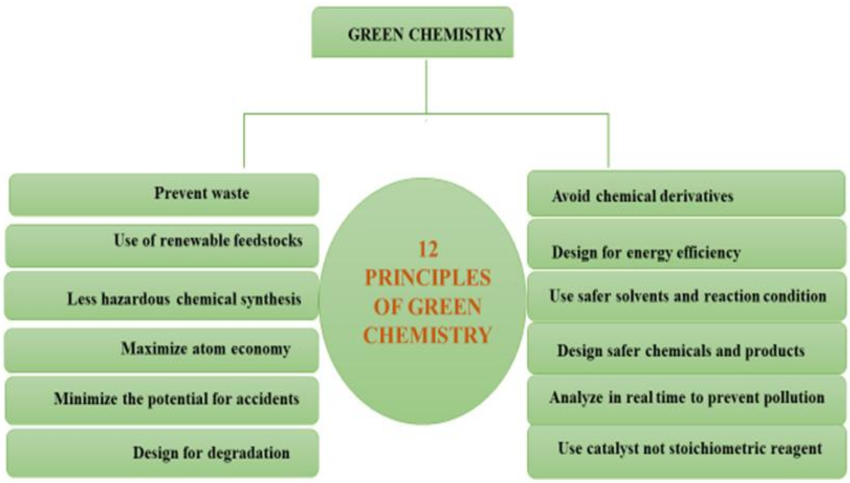

Figure 2: Principles of green chemistry

Figure 3: Characteristics of herbal conjugated nanoparticles

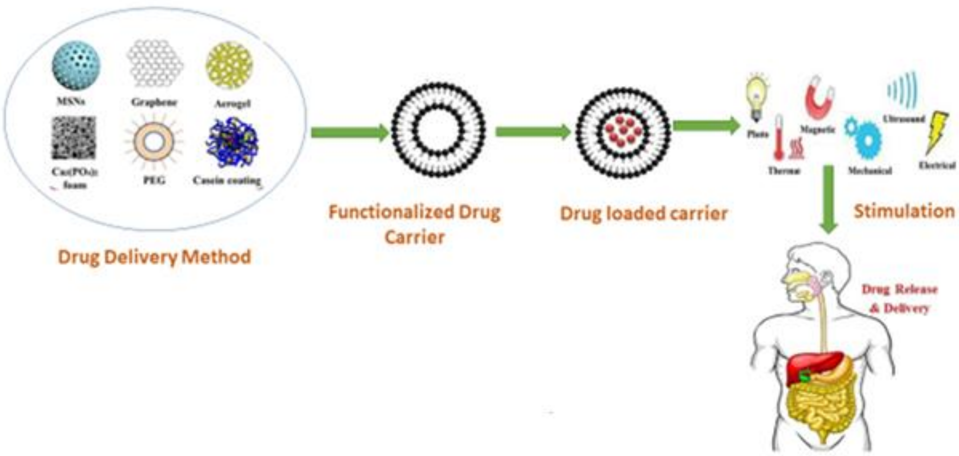

Figure 4: Nano-drug delivery system

CONCLUSION

Researchers are increasingly focused on herb-mediated green synthesis of nanoparticles due to its biodegradable nature and environmental benefits. This method employs various plant components, such as stems, flowers, and peels, to synthesize nanoparticles efficiently and consistently. Various physicochemical factors influence the dimensions and morphology of phytonanoparticles (PNPs). Plant extracts function as reducing agents, facilitating the bioreduction of metal salts to produce nanoparticles. Further investigation is necessary to identify the specific phytochemicals involved in nanoparticle synthesis. Identifying these molecules enables scientists to exert greater control over the size and shape of nanomaterials, thereby expanding their potential applications in medicine, industry, and agriculture. The biogenic synthesis of phytonanoparticles demonstrates significant potential for disease treatment. Although still in its early stages, recent advancements indicate a promising future. The development of non-toxic phytonanoparticles for potential pharmaceutical applications is of significant importance. Furthermore, further investigation into NP-containing formulations is crucial for the advancement of PNP-mediated drug delivery systems. PNPs are emerging as promising candidates for clinical diagnosis and therapies due to their stability and adjustable toxicity. Improvements in existing drug delivery methods could enhance efficacy and reduce the toxicity associated with synthetic drug formulations.

Conflict of interest

There is no conflict of interest.

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