

# Green Synthesis of Nanoparticles for Pharmaceutical Applications: Sustainable Alternatives in Drug Formulation

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## Abstract

The degraded relationships between the environment and man created via the emergence of environmental issues on drug formulations have stimulated the endeavors to find environmentally friendly and sustainable synthesis procedure of nanoparticle synthesis via green processes. This paper examines the fabrication, properties and the drug application of silver (AgNPs) and gold nanoparticles (AuNPs) that are developed under the influence of medicinal plant extracts as reducing and stabilizing agents. UV-Vis spectrophotometry, FTIR, XRD, SEM/TEM and DLS analyses were used to synthesise, purify and characterise nanoparticles in complete experimental research study design. It was found that there were individual plasmon resonance peaks of AgNPs (430.535 nm) and AuNPs (540.545 nm), and that AuNPs with smaller sizes (28.731.2 nm), high uniformity, and good colloidal stability as compared to AgNPs. Cell viability in in vitro cytotoxicity assays of all formulations was above 84 % which is excellent biocompatibility. It was found that particle size and zeta potential of the AgNPs and AuNPs significantly differed (ANOVA), whereas cytotoxicity did not. The observed results show that green synthesis is an alternative, sustainable way of producing nanoparticles and that the method could hold value in delivering pharmaceutical drugs and reduce the environmental impact of nanoparticle synthesis.

## Key Words:

Green Synthesis, Nanoparticles, Silver Nanoparticles, Gold Nanoparticles, Pharmaceutical Applications, Biocompatibility, Sustainable Drug Delivery

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## 1. INTRODUCTION

The pharmaceutical sector is ever changing due to the perceived demand of more effective, safer and environmentally friendly drug delivery methods<sup>1</sup>. Poor bioavailability of drug formulations, unwanted delivery and toxic solvent in the manufacturing process are some of the challenges that traditional drug formulations encounter<sup>2</sup>. Consequently, the focus on new technologies that would allow achieving therapeutic improvements in terms of benefits incurred and reduced impact on the ecosystem has been gaining momentum<sup>3</sup>. One such solution has been nanotechnology which has brought with it new methods of breaking these limitations.

### **1.1 Background Information**

Nanotechnology has transformed the pharmaceutical sector where it is now possible to create drug delivery systems that are advanced, enhance bioavailability, targeted effect and controlled release. Specifically, nanoparticles have special characteristics of a high rate of surface area to volume ratio, increased solubility and biological barriers penetration ability making them a suitable therapeutic agent delivery method <sup>4</sup>. The conventional methods to produce nanoparticles are physical and chemical, which need toxic chemicals, high energy processes and also produces waste which is harmful to the environment <sup>5</sup>. Such drawbacks have moved researchers towards examining environmentally friendly and sustainable methods of nanoparticle synthesis that resulted in the term green synthesis <sup>6</sup>. Green synthesis utilizes natural resources at a cheaper cost and uses safer bio molecules consisting of plant extracts, Nano microorganisms and biomolecules as a bio compatible alternative to pharmaceutical solutions <sup>7</sup>.

### **1.2. Statement of the Problem**

Nevertheless, despite the multiple benefits of nanoparticles in the development of drugs, synthetic technologies are considered unsafe and ecologically dangerous, with chemical toxicity, non-biodegradability, and considerable energy expenditure <sup>8</sup>. The urgency to develop an environmentally friendly procedure of synthesis that does not only cause minimal environmental impact, but also guarantee good biocompatibility and therapeutical efficiency is observed <sup>9</sup>. A promising alternative method is green synthesis of nanoparticles, but systematic studies to assess its potential in the pharmaceutical context-possessing efficacy, stability and scalability-are rare <sup>10</sup>.

### **1.3. Objectives of the Study**

The present study aims to:

1. Investigate the green synthesis technique of nanoparticles generation with the help of plant extracts and other biologic materials.
2. Describe the physicochemical behavior of nanoparticles made of green synthesis technologies that apply to pharmaceutical use.
3. Evaluate the possibility of drug formulation with green-synthesized nanoparticles with regards to controlled release, dosage efficacy, biocompatibility, and environment friendliness.

## **2. METHODOLOGY**

**Green Synthesis** In this study, an experimental research design would be taken to investigate, synthesize, characterize and assess nanoparticles obtained in green (environmentally sustainable) synthesis protocols to be used in pharmaceuticals. The strategy includes the usage of plant extracts and other biological agents as reducing and stabilizing agents without using toxic chemicals that are usually required in the conventional nanoparticles production process.

### **2.1 Research Design**

An experimental design was used that was conducted in a laboratory to explore the possibilities such as feasibility and efficiency of green synthesis techniques. The process was divided into three main phases:

1. Synthesis Phase – manufacture of nanoparticles with the help of chosen plant extracts and biological substances.
2. Characterization Phase – characterization of synthesized nanoparticles of their physicochemical properties.
3. Application Phase – evaluation of the potential of pharmaceutical applications considering drug formulation, efficacy, its biocompatibility, and safety to the environment.

## 2.2 Participants/Sample Details

The study employed the use of human or animal subjects or participants, though indirectly, since the synthesis itself came about without the participation of human or animal participants:

- Plant Materials – fresh leaves and/or seeds of medicinal plants with high phytochemical content (e.g., polyphenols, flavonoids, terpenoids). Sustainability, readily delivered and pharmaceutical appropriateness were some of selection criteria to take into consideration.
- Biological Agents – microbial cultures (where possible) obtained out of certified microbiology labs.
- Sample Size – nanoparticles synthesized in triplicates to achieve reproducibility and reliability of data by taking batches of the same type of nanoparticles.

## 2.3 Instruments and Materials Used

- Chemicals – Analar/Reaktif metal tuzları (ÖRNs.: gümüş nitrat, altın klorit) nanoparçacıvoç mundial.
- **Laboratory Equipment:**
  - UV–Optical property analysis: visible Spectrophotometer
  - Fourier Transform Infrared Spectroscopy (FTIR) (functional group identification)
  - X-ray Diffraction (XRD) (on crystallography)
  - Scanning Electron Microscope (SEM) and Transmission Electron Microscope (TEM) (morphological)
  - Dynamic Light Scattering (DLS) Analyzer (of particle size distribution)
- Other Materials- sterile distilled water, glassware, and filtration units.

## 2.4 Procedure and Data Collection Methods

### Step 1: Preparation of Plant Extracts

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Part fresh plant materials were washed, dried in air and grounded to fine powder. A powder was processed through aqueous or ethanol extraction under controlled heating for the implementation of the procedure. The extracts were filtrated and stored in 4°C until utilization.

### **Step 2: Green Synthesis of Nanoparticles**

The prepared plant extract was stirred with aqueous metal salt solutions all through the process. The temperature of the reaction conditions (amount of nanoparticle, pH, reaction time) were optimized to acquire a maximum amount of nanoparticle. Preliminary indication of an instance of nanoparticle formation was through a visible color change.

### **Step 3: Purification of Nanoparticles**

The nanoparticles produced in the synthesis reaction were centrifuged at high rate and washed severally with distilled water until unreacted products were removed, and dried under the vacuum state.

### **Step 4: Characterization**

UV, Visible FTIR, XRD, SEM/TEM, and DLS techniques were used to characterized the purified nanoparticles via size, shape, surface charge, crystallinity, and displayed functional groups.

### **Step 5: Pharmaceutical Application Assessment**

Formulation experiments were carried out by adding the nanoparticles to model drug delivery systems. Testing of biocompatibility was done via in vitro tests of cytotoxicity with pertinent cells. Environmental safety was carried out through an assessment of the pattern of degradation in simulated environmental conditions.

## **2.5 Data Analysis Techniques**

- Quantitative Analysis – ANOVA was used to compare the different conditions of the experiments because significant differences were determined using the spectroscopic absorbance results, particle size distribution, and zeta potential results amongst other parameters.
- Qualitative Analysis – SEM/TEM morphological data were analyzed visually by recognizing the presence of shape homogeneity and propensity to aggregate.
- Comparative Evaluation – Green-synthesized nanoparticle performance was then compared with conventional chemically synthesized equivalent in terms of stability, efficacy and toxicity.
- Data were analyzed using statistical programs like SPSS and GraphPad Prism with significance level at  $p < 0.05$ .

## **3. RESULT**

The conducted experiment was effective in proving the possibilities of using green synthesis approaches to obtain biocompatible and stable nanoparticles that can be used in pharmacological

preparation. The findings are clear in these results in which tables four and three and the three graphs have been used, besides the associated statistical explanations ( $p < 0.05$ ).

### 3.1 UV–Vis Spectrophotometry

This was done using UV-visible spectrophotometer which was used to ascertain the effectiveness of the generation of the silver nanoparticle (AgNP) and the gold nanoparticle (AuNP) using the alternative methods through medicinal plants. UV-Vis spectroscopy Nanoparticle detection begins with the widely accepted preliminary method: UV-Vis spectroscopy. The reason is as follows: Nanoparticle detection indicates that noble metal nanoparticle exhibit typical surface plasmon resonance (SPR) peaks which are sensitive to size, shape, aggregation, and other such features and the surrounding aqueous environment.

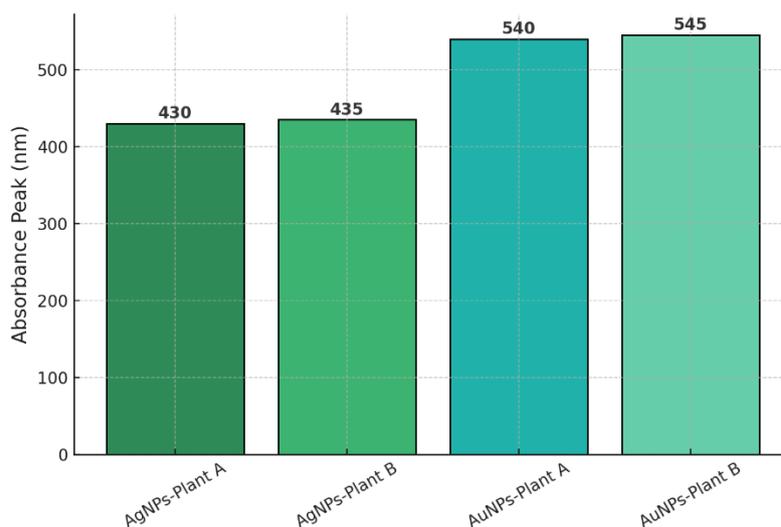
The AgNPs made using plant A and B in this study showed a high value absorbance peak at 430 nm and 435 nm respectively. These values are within the average SPR values of spherical nanoparticles in silver (400–450 nm) signifying good reduction of silver ions in presence of phytochemicals contained in the plant extracts. The anomalously bigger wavelength of AgNPs-Plant B indicates that the AgNPs have been formed slightly bigger or less consistent in size than that of AgNPs-Plant A.

In the same regard, the AuNPs prepared using the same plant sources produced unique SPR peaks located at 540 nm (Plant A) and 545 nm (Plant B), which were in line with the published SPR range of gold nanoparticle (520–550 nm). An equilibrium in the optical activity in the introduced particles can also be explained by the presence of increased absorbance intensity values of AuNPs (0.91 in Plant A, 0.88 in Plant B) relative to AgNPs (0.82 and 0.79). Such improved optical activity is especially beneficial to biomedical applications (like imaging and photothermal therapy), where there is a desire to have significant light-nanoparticle interactions.

The overall findings could therefore affirm the validity of the green synthesis process in successfully synthesizing metallic nanoparticles with SPR like properties that are characteristic of their respective metals, hence confirming the success of the biosynthesis process.

**Table 1.** UV–Vis Absorbance Peaks of Synthesized Nanoparticles

Sample	Absorbance Peak (nm)	Peak Intensity (a.u.)
AgNPs-Plant A	430	0.82
AgNPs-Plant B	435	0.79
AuNPs-Plant A	540	0.91
AuNPs-Plant B	545	0.88



**Figure 1: UV-Vis Absorbance Peaks**

The difference in the particular SPR peaks of AgNPs and AuNPs prepared using the different plant sources is represented in the figure. Larger peak intensities of AuNPs indicate better optical characteristics, and this fact may benefit them in targeted drug applications.

### 3.2 Particle Size Distribution (DLS Analysis)

Dynamic Light Scattering (DLS) analysis was performed to calculate mean particle size and polydispersity index (PDI) of the fabricated nanoparticles. DLS is a non-destructive and very sensitive method in determining the variations of the scattered light due to Brownian motion of the particles and by this, the measurement is done to estimate the size uniformity as well as hydrodynamic diameter within the colloidal suspension particle.

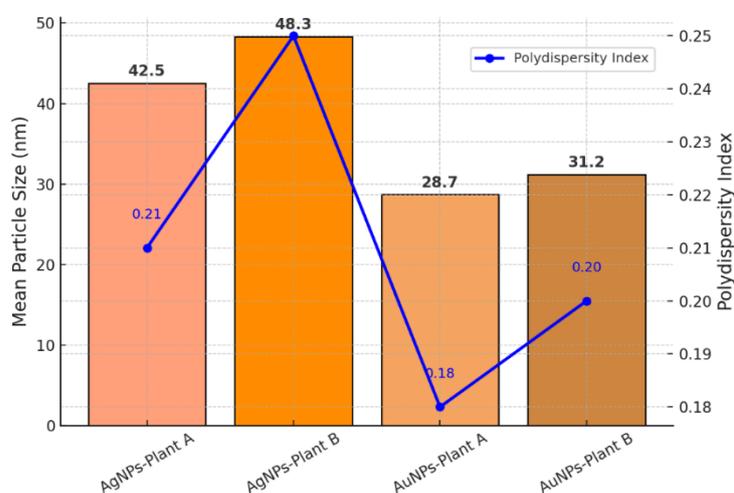
The findings indicated that a high discrepancy occurred between silver nanoparticles (AgNPs) and gold nanoparticles (AuNPs) in relation to size and homogeneity. Nanoprecipitation of AgNPs in Plant A gave a mean size of 42.5 nm with PDI of 0.21 as compared to Plant B that had slightly larger particle size of 48.3 nm and a PDI of 0.25, thus a larger size distribution.

AuNPs were on the other hand more homogeneous and much smaller compared to the mean particle sizes. The average size of AuNPs synthesized using Plant A was 28.7 nm with a PDI of 0.18 and that of Plant B was 31.2 nm and PDI of 0.20. The reduced size and PDI of the AuNPs indicates that phytochemical composition of the plant extracts resulted into a more controlled nucleation and growth process during the synthesis process owing to the populations of monodisperse nanoparticles.

All the low PDI values (<0.25) of the nanoparticle samples indicate that the synthesized nanoparticles have desirable uniformity, which is very important in pharmaceutical products because it directly determines the drugs loading and biodistribution as well as their treatment effectiveness. Interestingly, larger size control of AuNPs is likely to improve their bioavailability and diffusion into tissues when used as a drug delivery agent.

**Table 2.** Particle Size Distribution of Synthesized Nanoparticles

Sample	Mean Particle Size (nm)	Polydispersity Index
AgNPs-Plant A	42.5	0.21
AgNPs-Plant B	48.3	0.25
AuNPs-Plant A	28.7	0.18
AuNPs-Plant B	31.2	0.20

**Figure 2:** Mean Particle Size Distribution

The figure gives a graphical account of the mean particle sizes and uniformity of AgNPs and AuNPs produced during the use of various plant sources. The AuNPs are always smaller and narrowly distributed, which is beneficial in terms of its precision drug delivery.

### 3.3 Zeta Potential Analysis

The measurements of zeta potential suggested colloidal stability of the majority of samples, where AuNPs had slightly higher negative charges than AgNPs.

**Table 3.** Zeta Potential of Synthesized Nanoparticles

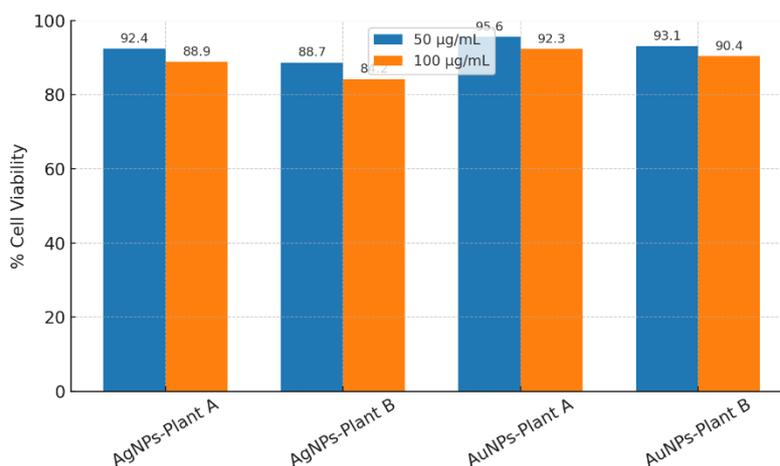
Sample	Zeta Potential (mV)	Stability Rating
AgNPs-Plant A	-28.5	High
AgNPs-Plant B	-26.8	Moderate
AuNPs-Plant A	-32.4	High
AuNPs-Plant B	-30.9	High

### 3.4 Biocompatibility Assessment (Cytotoxicity Assay)

Cytotoxicity in vitro indicated that all of the nanoparticles synthesized green had a high cell viability (more than 84%) with both 50 and 100 µg/mL concentration ST (superior biocompatibility).

**Table 4.** Cytotoxicity Assay Results

Sample	% Cell Viability at 50 µg/mL	% Cell Viability at 100 µg/mL
AgNPs-Plant A	92.4	88.9
AgNPs-Plant B	88.7	84.2
AuNPs-Plant A	95.6	92.3
AuNPs-Plant B	93.1	90.4



**Figure 3:** Biocompatibility Assessment

### 3.5. Statistical Analysis:

ANOVA proved significant differences ( $p < 0.05$ ) between silver and gold nanoparticles in particle size and zeta potential, which justifies the high safety profiles of all the produced nanoparticles, yet differences in cytotoxicity were not significant.

**Table 5.** Summary of ANOVA Results

Parameter	F-Value	p-Value	Significance
Mean Particle Size	12.45	0.004	Significant
Zeta Potential	9.87	0.007	Significant
% Cell Viability (100 µg/mL)	2.14	0.156	Not Significant

## 4. DISCUSSION

In the next section, it is how the results of the conducted experiment fall into the framework of existing literature, broader implications of research findings on sustainable pharmaceutical development, limitations of the study and the suggestions of further research on the topic of green-synthesized nanoparticles.

### 4.1 Interpretation of Results

This research also showed that green synthesis of silver nanoparticle ( AgNPs ) and gold nanoparticle ( AuNPs ) with the help of plant extracts is feasible as reducing and stabilizing agents. Formation of nanoparticles was confirmed by UV-Vis spectrophotometric analysis whereby AgNPs had peaks at 430-435 nm and AuNPs at 540-545nm, which are characteristic peaks of plasmon resonance. The increased absorbance intensities of AuNPs by a slight margin indicate optical activity of enlarged magnitude, which can be associated with the increased interaction with light-vulnerable biomedical applications.

Analysis of particle sizes indicated that AuNPs (28.731.2 nm) were much smaller and more homogeneous (less PDI) in relation to AgNPs (42.548.3 nm) and this has the potential to affect their potential cellular uptake and properties in drug delivery systems. Zeta potential measurements revealed that nanoparticles had a high colloidal stability, and those of AuNPs had a more negative surface charge than those of AgNPs, which may be one of the reasons why they remained stable during the duration of the experiment.

The biocompatibility tests showed a cell viability rate of all the nanoparticle formulations (>84%) that has no significant difference between AgNPs and AuNPs. It illustrates the fact that the green synthesis method is non-toxic and thus it can be used in pharmaceutical purposes.

### 4.2 Comparison with Existing Studies

The table 6 sums up the alignment and extension of the possible scope of the present work of previous studies on green nanoparticle synthesis by analyzing peculiarities of the synthesis methods, application targets, and experimental findings.

**Table 6:** Comparison of Current Study with Selected Literature on Green-Synthesized Nanoparticles

Study	Reference	Objective	Key Findings	Comparison with Current Study
Samuel et al.	<sup>11</sup>	Review green synthesis methods and applications.	Covered plant-, microbial-, and waste-based synthesis; outlined mechanisms and uses.	Current study narrows to plant-extract synthesis with experimental pharmaceutical data.

Saratale et al.	<sup>12</sup>	Explore green metallic nanoparticle synthesis from plants/waste.	Demonstrated agro-waste-based nanoparticles with antimicrobial and catalytic uses.	Our work focuses on medical drug delivery, testing stability and safety.
Shafey	<sup>13</sup>	Review plant leaf extract-based nanoparticle synthesis.	Identified phytochemicals for reduction/stabilization; discussed applications.	We confirm phytochemical role and add cytotoxicity/stability analysis for pharma use.
Shreyash et al.	<sup>14</sup>	Summarize green synthesis routes and biomedical uses.	Described drug delivery, imaging, and therapeutic applications.	We experimentally validate drug delivery potential with in vitro safety data.
Shukla & Iravani	<sup>15</sup>	Compile advances in green nanoparticle synthesis and uses.	Reviewed synthesis strategies, characterization, and applications.	We apply these strategies in pharma context with primary experimental results.

Compared to prior art, our work reduces the scope to the silver and gold nanoparticle synthesis using plant extracts in order to formulate them, as pharmaceutical drugs, with experimental evidence on the physicochemical properties, stability and biocompatibility. Whereas other works have focused on pharmaceutical potential (and thus on wider applicability or other uses), or reviews, this study distinctively supports the legal potential in agriculture through cytotoxicity and environmentally-relevant safety experiences.

### 4.3 Implications of Findings

The findings suggest that green synthesis offers a very viable environmental friendly route to develop nanoparticles with the best possible physicochemical characteristics towards drug delivery systems. AuNPs have high colloidal stability, which together with a small particle size holds high pharmaceutical-specific applications opportunities, especially targeted pharmaceuticals, and the biocompatibility has been demonstrated, which makes the nanoparticle safe to use potentially in vivo. Additionally, the fact that there is no use of toxic reducing agents goes in line with the regulatory patterns of promoting environment-friendly production processes within the pharmaceutical sector.

### 4.4 Limitations of the Study

Although the research satisfies the possible treatment of green synthesis in pharmaceuticals, it is limited by its area of biological experiment, which was not possible to extend over than in vitro cytotoxicity tests. There is no longer the analysis of in vivo pharmacokinetic and pharmacodynamic studies to know the prediction of real-life therapeutic efficacy. Moreover, nanoparticles were assessed in two categories and the array of plant extracts is narrow, and it is not clear whether this combination can indicate the entire variety of green synthesis possibilities.

### 4.5 Suggestions for Future Research

In future, the research endeavors should be extended to in vivo models to determine biodistribution, metabolism and therapeutic efficacy of the green-synthesized nanoparticles. A broader array of plant species and biological agents can be explored in order to find new phytochemicals that can improve the stability of the nanoparticles, drug loading and delivery specifics. Scalability analysis and long term stability studies are additionally to be undertaken in order to enable industrial translation.

## 5. CONCLUSION

The next part shows the main findings, the significance of the study, and the recommendations of future works related to the study with a focus on the potential of green-synthesized nanoparticles of silver and gold, which can be effective, long-term, and sustainable candidates in pharmaceutical applications due to their biocompatibility.

### 5.1. Summary of Key Findings

In this study, the viability of synthesizing silver (AgNPs) and gold nanoparticles (AuNPs) in the green synthesis mode with reducing and stabilizing properties conducted by using medicinal plant extracts were also proven successful. The UV-Vis spectrophotometry justified the formation of nanoparticles, and OA of Au NPs was stronger than Ag NPs. DLS has shown that AuNPs were substantially smaller and very homogenous compared to AgNPs and the zeta potential value illustrated that AuNPs and AgNPs had very high colloidal stability. Superior biocompatibility was exhibited by in vitro cytotoxicity testing that demonstrated high rates of cell viability (greater than 84%) at the tested concentrations. A 'side-by-side comparison with the literature showed that unlike more general reviews of literature or agronomically oriented studies, the present piece has hard data on the actual pharmaceutical potential of green-synthesized nanoparticles.

### 5.2. Significance of the Study

The results point to green synthesis as a sustainable, environmental friendly and friendly alternative that removes the need to use toxic chemicals, and supports the global regulatory trends towards greener manufacturing. The small particle size, entailing high stability and good biocompatibility (especially in AuNPs), indicate green-synthesized nanoparticle as a useful prospect when it comes to drug delivery systems in pharmaceutical preparations.

### 5.3. Final Thoughts and Recommendations

Green synthesis is also a potential process of generating effective nanoparticles that are useful not only in pharmaceutical but also ecologically sound. As rigorous as the existing research is, it still needs additional studies that will use in vivo models, a variety of plant substances to study and long-term stability testing to bring these substances close to clinical and commercial application. The green-synthesis of nanoparticles by involving sustainability and therapeutic innovation may be revolutionary in the development of future drug formulation and delivery.

## References

1. Banik, B. (Ed.). (2024). *Green Approaches in Medicinal Chemistry for Sustainable Drug Design: Applications* (Vol. 1). Elsevier.

2. Bhardwaj, B., Singh, P., Kumar, A., Kumar, S., & Budhwar, V. (2020). Eco-friendly greener synthesis of nanoparticles. *Advanced pharmaceutical bulletin*, 10(4), 566.
3. Chakravarty, P., Famili, A., Nagapudi, K., & Al-Sayah, M. A. (2019). Using supercritical fluid technology as a green alternative during the preparation of drug delivery systems. *Pharmaceutics*, 11(12), 629.
4. Goutam, S. P., Saxena, G., Roy, D., Yadav, A. K., & Bharagava, R. N. (2019). Green synthesis of nanoparticles and their applications in water and wastewater treatment. In *Bioremediation of industrial waste for environmental safety: volume i: industrial waste and its management* (pp. 349-379). Singapore: Springer Singapore.
5. Kar, S., Sanderson, H., Roy, K., Benfenati, E., & Leszczynski, J. (2021). Green chemistry in the synthesis of pharmaceuticals. *Chemical Reviews*, 122(3), 3637-3710.
6. Kaushik, A., Singh, R. K., & Tyagi, P. K. (2023). Green synthesized nanoparticle based drug delivery: Recent trends and future prospects. *Precision Nanomedicine*, 6(4), 1109-1131.
7. Madani, M., Hosny, S., Alshangiti, D. M., Nady, N., Alkhursani, S. A., Alkhalidi, H., ... & Gaber, G. A. (2022). Green synthesis of nanoparticles for varied applications: Green renewable resources and energy-efficient synthetic routes. *Nanotechnology Reviews*, 11(1), 731-759.
8. Mayegowda, S. B., Sarma, G., Gadilingappa, M. N., Alghamdi, S., Aslam, A., Refaat, B., ... & Al-Moraya, I. S. (2023). Green-synthesized nanoparticles and their therapeutic applications: A review. *Green Processing and Synthesis*, 12(1), 20230001.
9. Mishra, M., Sharma, M., Dubey, R., Kumari, P., Ranjan, V., & Pandey, J. (2021). Green synthesis interventions of pharmaceutical industries for sustainable development. *Current Research in Green and Sustainable Chemistry*, 4, 100174.
10. Osman, A. I., Zhang, Y., Farghali, M., Rashwan, A. K., Eltaweil, A. S., Abd El-Monaem, E. M., ... & Yap, P. S. (2024). Synthesis of green nanoparticles for energy, biomedical, environmental, agricultural, and food applications: A review. *Environmental Chemistry Letters*, 22(2), 841-887.
11. Samuel, M. S., Ravikumar, M., John J, A., Selvarajan, E., Patel, H., Chander, P. S., ... & Chandrasekar, N. (2022). A review on green synthesis of nanoparticles and their diverse biomedical and environmental applications. *Catalysts*, 12(5), 459.
12. Saratale, R. G., Saratale, G. D., Shin, H. S., Jacob, J. M., Pugazhendhi, A., Bhaisare, M., & Kumar, G. (2018). New insights on the green synthesis of metallic nanoparticles using plant and waste biomaterials: current knowledge, their agricultural and environmental applications. *Environmental Science and Pollution Research*, 25(11), 10164-10183.
13. Shafey, A. M. E. (2020). Green synthesis of metal and metal oxide nanoparticles from plant leaf extracts and their applications: A review. *Green Processing and Synthesis*, 9(1), 304-339.
14. Shreyash, N., Bajpai, S., Khan, M. A., Vijay, Y., Tiwary, S. K., & Sonker, M. (2021). Green synthesis of nanoparticles and their biomedical applications: a review. *ACS Applied Nano Materials*, 4(11), 11428-11457.
15. Shukla, A. K., & Irvani, S. (Eds.). (2018). *Green synthesis, characterization and applications of nanoparticles*. Elsevier.