

Synthesis Of Nanoparticles Used Plant Extract

Hawraa H. Esmael¹, Zahraa A. Rasheed² and Rafal Shakeeb alanee¹

¹ Clinical laboratory Science Branch, College of Pharmacy, Al- Nahrain University, Baghdad, Iraq.

² Department of Physics, College of Education, Al-Iraqia University, Baghdad, Iraq.

Abstract

Numerous potential applications in the biological and environmental fields are presented by the development of green nanoparticles. In particular, green synthesis aims to employ less toxic chemicals. For instance, using organic resources, such as plants, is usually permissible. Plants also contain lowering and capping agents. Here, we discuss the basics of green chemistry and look at new applications for plant-mediated synthesis-produced nanoparticles. Nanoparticles include platinum, palladium, copper, silver, gold, zinc oxide, and titanium dioxide.

Keywords: nanotechnology, Medicinal plants, plant extract, green synthesis, nanoparticles, medical application

Introduction

One of the most interesting areas for creating and applying materials with interatomic structural features is nanotechnology. Nanotechnology was created. 21st-century scientific breakthroughs Nanoparticles are particles that have a diameter of less than 100 nanometers. The size component was less than 100 nm, and the measurements were on a one-billionth scale (1) The remarkable daily advancements in nanotechnology have opened up new, fundamental, and applied frontiers in area of study, namely materials science and engineering, including applied microbiology, nano biotechnology, surface-enhanced Raman scattering (SERS), and quantum dots(2), Numerous significant advancements, from the supply of nanoscale (nanoparticles) to optics, instrumentation, and biomedical science, high-energy vehicle science, instrumentation, pharmacy, planning, optoelectronic applications, optical cables, and remote devices. Additionally, because of their massive, bulk, and small (nm) sizes that alter tissue and because their structural characteristics differ from those of many similar synthetic chemicals, nanoparticles are used in significant fields. Many researchers and specialists are interested in it and recognize its distinctiveness (3, 4).

The different components in the field vary, even though many nanoparticles exhibit toxicity at the nanoscale. Green synthetic materials and nanotechnology work together to improve the environment. From crops, crops, and other resources to tackle the pollution issue. Using a clean "scientific" climate system that views microorganisms as invisible growth and growth factors, experts have created a number of engineering approaches to transport nanoscale particles that offer significant benefits to the environment and climate, Numerous studies have been conducted to produce metal nanoparticles using bacteria like *Penicillium* sp. and *Fusarium oxysporum* as well as microorganisms like *Bacillus subtilis*(5).

Developing a plant that can synthesize a range of nanoparticles is the aim of this study, with green synthetics and environmental reactions being the most well-known features. Researchers have become interested in this plan because of its ease of use and efficiency, as well as plant extracts and different metabolite sources (6).

Plant extracts, including leaves, roots, flowers, etc., with precursor elements are magnetically stirred at a certain synthesis temperature (usually ranging between 100-120 °C) to contribute as a capping or reducing agent in the synthesis of metal oxide nanoparticles. Subsequently, the resultant solution is subjected to centrifuging process while the supernatant is castoff. The obtained metal oxide nanoparticles are naturally dried and grinded for further use (7), Natural extracts are intricate concoctions of compounds with biological characteristics that are mostly obtained from the roots, leaves, stems, or fruits of therapeutic plants. One of the most notable biological effects that plant extracts

exhibit are their antifungal, anticancer, antioxidant, hypoglycemic, antihypertensive, and antibiotic qualities (8).

Medicinal plants

Medicinal plants have been a major source of medications for thousands of years. Many of the medications utilized in 21st-century medicine were created using vegetable origins. Plants have long been utilized for its anti-inflammatory, bactericidal and antioxidant properties. The process of finding, evaluating, and incorporating novel compounds into existing treatment regimens is extremely difficult, costly, and time-consuming. Since it is generally known that, in certain circumstances, the activity of the phytocomplex is greater than that of pure phytochemicals because of the synergism of molecular structures, attention is frequently focused on the research of plant extracts(9).

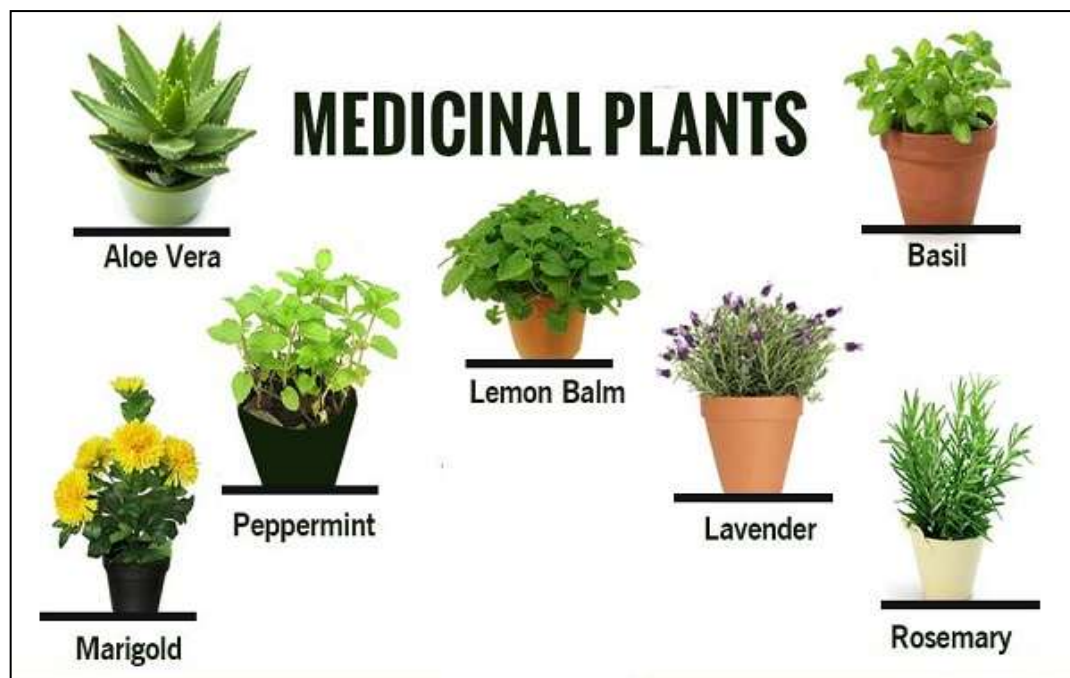


Figure (1) different type of medical plant (10)

Many of the many different types of modern medications, including aspirin, are produced using medicinal plants in an indirect manner. Among the many food crops with medicinal qualities is garlic. Investigating medical Plants can help us understand plant toxicity and protect humans and animals from natural toxins. The medicinal qualities of plants are derived from the creation of secondary metabolites. Because of this, there have been increased waves of interest in studying the chemistry of natural products (11). The World Health Organization (WHO) has acknowledged the value of traditional medicine and established protocols, standards, and guidelines for botanical medications. Agro-industrial technologies must be applied for the manufacture of herbal medications, the processing of medicinal plants, and their cultivation, many contemporary medications are made indirectly from plants, and medicinal plants are a source of new pharmaceuticals (12).

Green synthesis nanoparticles

Using natural resources as a starting material and/or plant extracts as a reducing agent while producing metal oxide nanoparticles are examples of green approaches. The goal of green synthesis of nanoparticles is to reduce waste production and use sustainable procedures. The development of nanotechnology in recent years has placed a strong emphasis on environmentally friendly procedures that use nontoxic precursors and mild reaction conditions (13). Environmental friendliness will be immediately improved by green synthesis of materials and nanomaterials, which are created through regulation, control, cleanup, and remediation processes. Thus, a number of elements, such as waste prevention or minimization, derivatives and pollution reduction, the use of safer (or non-toxic) solvents

and auxiliaries, and the use of renewable feedstock, can be used to describe some of the fundamental ideas of "green synthesis." Green synthesis is necessary to prevent the creation of undesirable or hazardous byproducts by accumulating dependable, environmentally friendly, and sustainable synthesis processes (14).

This requires the use of natural resources, such as organic systems, and ideal solvent systems. Green synthesis of metallic nanoparticles has been created to accept various biological constituents (e.g., bacteria, fungi, algae, and plant extracts). The utilization of plant extracts is one of the simpler and more environmentally friendly methods of mass-producing metal/metal oxide nanoparticles as opposed to bacterial and/or fungal-mediated synthesis. Different microbes can generate nanoparticles through a variety of ways. Enzymes convert the arrested metal oxide ions into metal oxide nanoparticles after the metallic ions are first trapped on the microbial cell surface or inside the cell (15).

Even though there are many different synthesis methods for making metal oxide nanoparticles, the green synthesis method is thought to be the most popular because it is environmentally friendly, doesn't use toxic chemicals, uses biological components as reducing and capping agents, doesn't require high pressure or external energy, and can be used to produce nanoparticles on a large scale (16). There are two distinct groups of biological and physicochemical mechanisms for the creation of nanoparticles: from the bottom up with a top-down strategy, Figure 2. Illustrates the creation of nanoparticles using a variety of biological and physicochemical techniques.

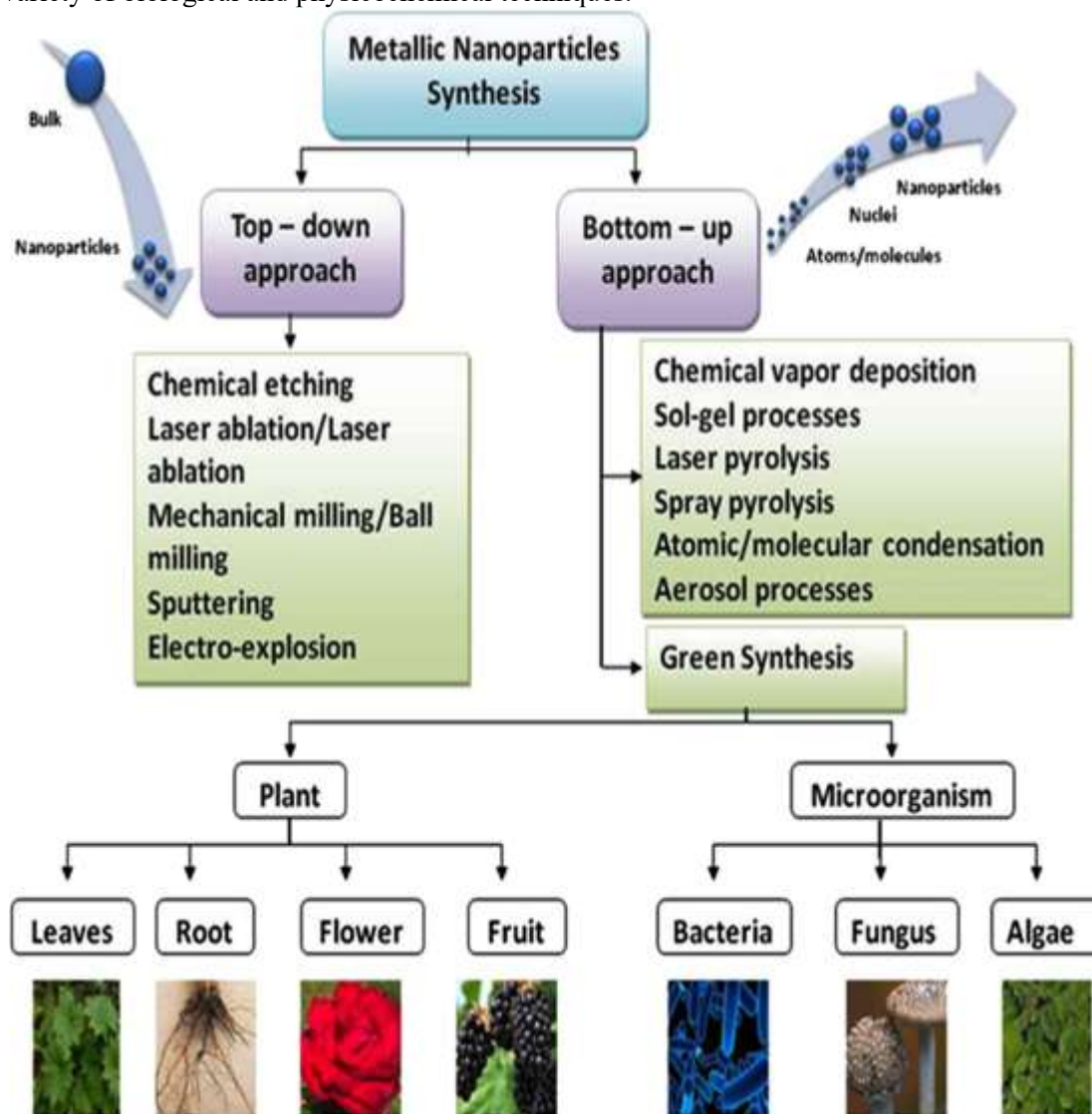


Figure (2) Nanoparticles synthesis via biological a physicochemical approaches (17)
Bottom-up method

Through a range of chemical and biological processes, atoms can self-assemble into new nuclei, which subsequently grow into a particle with nanoscopic dimensions, or they can be formed from tiny building blocks, such as atoms and molecules, using the bottom-up method. (Figure. 3a) (18).

Top-down method

This method uses a size reduction technique to create nanoparticles, which means that appropriate bulk material shrinks to tiny units using the proper lithographic techniques, such as milling, spitting, and crushing, as shown in Figure 3b. It is possible to carefully control the stability, shape, and size of nanoparticles by adjusting the temperature, pH, concentration of plant extract, metal salt solution, and incubation time. Palladium and platinum nanoparticle production was reviewed by Siddiqi et al. (19), who also provided a comprehensive synthesis process and discussed the possible uses of the nanoparticles as medicines, biosensors, diagnostics, medicine, and catalysts.

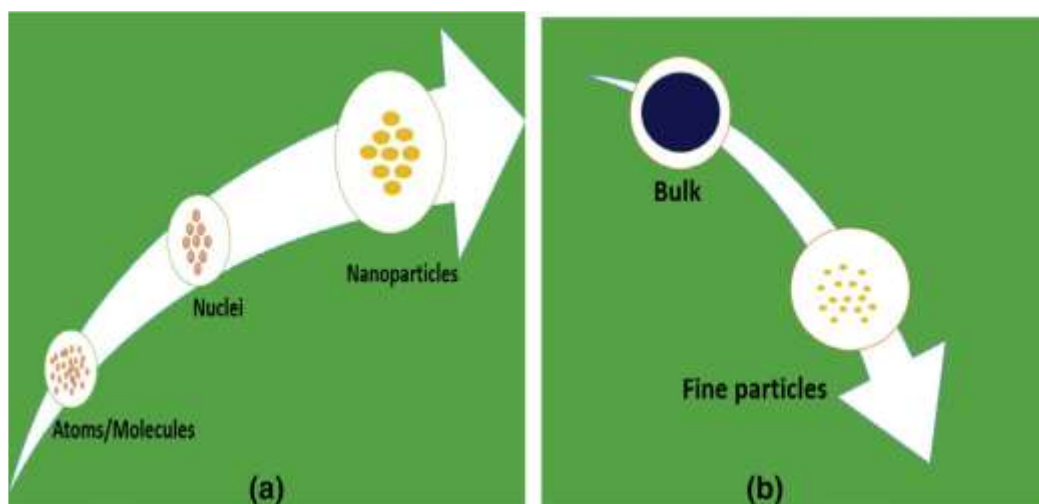


Figure (3) Synthesis protocols for nanoparticles: a bottom-up approach of nanoparticles through the self-assembly of different nuclei and a top-down method for size reduction nanoparticle synthesis (20).

Plants participation in the production of green nanoparticles

For the biosynthesis of nanoparticles using the aforementioned components, more research on green and nanoparticles is required. In this piece, Interactions between various cells and micro materials are possible.

Trees are noted for having low maintenance costs and tree trunks. Even at low temperatures, the breakdown of large and poisonous metals is uncommon, and plants show a great deal of potential for pollution and heavy metals that can solve the issue of natural pollution. Limiting nanoparticles to plants instead of industry has advantages since they can be absorbed by microbes through the amazing process of microbial culture (21).

Due to the remarkable phytochemicals of plants, various plant parts, including natural products, leaves, and roots, are used to produce green nanoparticles; parts of the plant can be cleaned with glue and then filled with purified water to hold the nanoparticles. The steady biosynthesis characteristic and the synthetic nanoparticle approach have lower energy than the pathway incorporating nanoparticles and plants (22).

Extraction of metal nanoparticles generated by biological processes

Leaves and blooms of certain plants can produce nanoparticles. plants in which plant components are carefully cleaned using tap water, sterilized using double-distilled water, and then allowed to dry at room temperature. Following drying, the sample is crushed and weighed. After that, the plant extract and Milli-Q H₂O are mixed to the proper concentration and heated to a boil while being continuously stirred.. After using Whatman filter paper to filter the resultant solution, the portion containing a clear solution was helpful for the sample (plant extract) (23).

In figure 4 show inexpensive and environmentally sustainable method for producing nanoparticles using extract from plants.

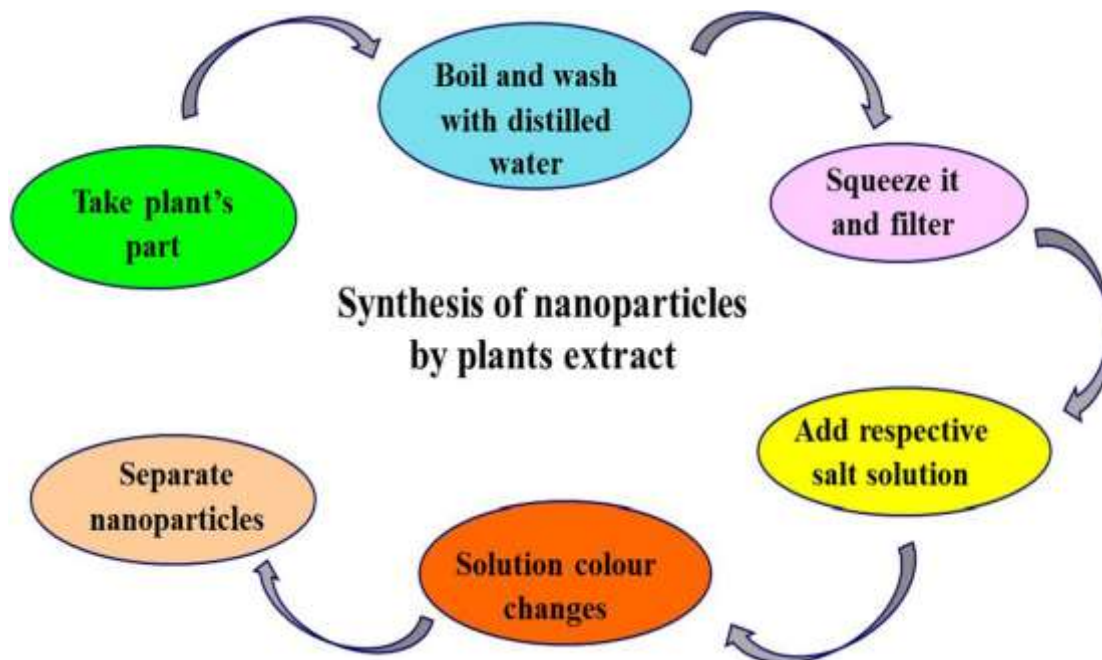


Figure (4) method for producing nanoparticles using extract from plants (24)

Metal nanoparticles

Metallic nanoparticles have special qualities including optical qualities and surface Plasmon resonance. Gold solutions, like a 20 nm solution, do have a golden yellow hue. Whereas 200 nm nanospheres are bluish in color, gold nanospheres are red rubies. Researchers in a variety of scientific and technological fields, including photography, medicine, and the development of antimicrobial and anticancer compounds, have shown a great deal of interest in noble metals, particularly silver and gold(25).

Good metal nanomaterials, including Au, Ag, and Cu, as well as alkali, maintain a wide adsorption elevation in the observable region of the electromagnetic solar range; factors, sizes, and shapes-observed metal Nanomaterials are extremely valuable because they are highly developed and advanced materials. All of these are made from prototypes made of metal. Because of its typical localized external Plasmon resonance (LSPR) phenomena, they are looking for unique optical-electrical characteristics (26, 27).

Due to their distinct physical and chemical characteristics from those of bulk metals, metallic nanoparticles have gained attention.

Numerous characteristics, such as high surface area, mechanical strengths, low melting point, magnetic, and optical characteristics.

Metallic nanoparticle-based catalysts are extremely active, selective, and long-lived for a variety of chemical processes.

A DVD disk with a storage capacity of 10 tetra bytes—roughly 2000 movies of convectional size—has been tested (28). Only the optical characteristics of the randomly oriented gold nanorods placed in the disk make this possible. Zijlstra and colleagues employed the optical spectrum and various polarization directions to store data (29).

Metal Oxide Nanoparticles

Metal oxide (MeO) nanoparticles (NPs), which come in a variety of sizes and forms and range in size from 1 to 100 nm, are one such class of nanomaterials. MeO-NPs are versatile due to their distinct

physical and chemical properties that are associated with their nanoscale size. MeO-NPs are essential components of solid oxide fuel cells, semiconductors, sensing, drug delivery, diagnostics, and catalysis (30).

Both high and low melting-point metals can be found in MeOs, which are formed when metal and oxygen atoms mix. MeOs have metallic, semiconductor, and insulator properties according to their various electronic structures (31). While insulator MeOs are made from metals in groups 1, 2, and 13–18 of the periodic table, metallic and semiconductor MeOs are made by combining oxides with metals from groups 3–12. MeONPs' various characteristics are what primarily contribute to their antibacterial action. The primary factor granting antibacterial activity to MeO-NPs is their surface alkalinity (32). Because they contribute to the medium's alkalinity, these alkali MeO-NPs are more soluble. Furthermore, the microbicidal property of positively-charged MeO-NPs is determined by their electrostatic nature (33). Consequently, MeO-NPs show promise as antibacterial agents against a variety of microorganisms, including ones that are resistant to drugs (34).

Toxicity of nanoparticles

Research on nanoparticles has been done in the therapeutic sciences in an effort to achieve specific pharmacological objectives (35). Metal oxide nanoparticles are an appealing scientific subject for various applications, particularly biological ones, due to their characteristics, which include reduced size, compound component, orientated structure, huge surface area, and form. However, a number of factors, including size, solubility, exposure, etc., might contribute to the toxicity of metal oxide nanoparticles (36). Ingestion, cutaneous exposure, and inhalation are the three most frequent ways that nanoparticles are exposed. Furthermore, when exposed to cells or biological fluids, the metal ion separates from the nanoparticle, which is the primary cause of toxicity for many metal oxide nanoparticles (37). Compared to a non-endocytosis entrance mechanism, internalization through endocytosis can result in far more serious cell injury. The remaining particles interact with the endothelial cells as the majority of the nanoparticles are removed by phagocytosis (38). This results in an increase in cytokines, the expression of adhesion molecules, the recruitment and adherence of monocytes, an elevation of nitric oxide levels, and a decrease in cell viability (39).

Medical application of nanoparticles

The cells that make up living things are usually 10 μm across. The cell components, however, are considerably smaller and fall into the sub-micron size range. Proteins are even smaller, typically measuring about 5 nm, which is similar to the size of the tiniest artificial nanoparticles (40). This straightforward size comparison suggests that we may use nanoparticles as tiny probes to see the cellular machinery without causing undue disruption (41). Nanotechnology is an enabling technology that works with items that are smaller than a nanometer. Nanotechnology is anticipated to advance at multiple levels, including materials, devices, and systems. One significant factor that is becoming more widely acknowledged in the medical field is the safety issues surrounding the handling and application of nanomaterial's (42).

The application of nanotechnology has already had a significant impact on medicine and medical sciences. Noble metal-based nanoparticles, especially Au and Ag NPs, have a wide range of applications, which highlights the importance of more study in this area. These structures have a vast amount of promise, including the ability to be used as drug delivery systems, parts that improve the efficacy of radiation-based anticancer therapy, molecular imaging support, and substances with antiviral, fungi-, and bactericidal qualities. (43).

Because nanoparticle-based therapeutics can be an ideal tool for the diagnosis and treatment of many diseases, with a focus on cancer, it is crucial to use them in clinical studies. But it's essential to surmount some obstacles brought on by the characteristics of some nanoparticles, like issues with porosity or biodegradability. Furthermore, not much is known about these nanoparticles' toxicity or how they interact with healthy, live cells (44). Improving the produced nanoparticles' pharmacokinetic characteristics is very crucial in order to ensure that they can reach the target site with high selectivity and undamaged (45).

By functionalizing the nanoparticles with the proper ligands, this can already be achieved. Additionally, employing a variety of noble metal-based nanoparticles in a comprehensive manner to sensitize cancer cells may result in better therapy outcomes (46).

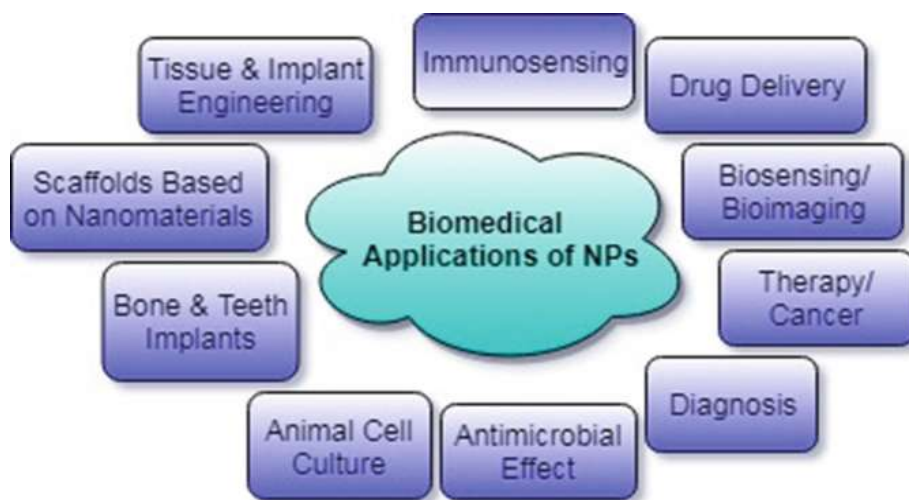


Figure (5) medical applications of nanoparticles (47)

Show medical applications in figure 5, there is no question that advances in nanotechnology have made it possible to diagnose and treat a variety of illnesses more successfully.

Nanomaterials are most commonly used in biology and medicine for fluorescent biological labels (48), drug and gene delivery, biodetection of pathogens, protein detection, DNA structure probing, tissue engineering, tumor destruction by heating (hyperthermia), separation and purification of biological molecules and cells, MRI contrast enhancement, and phagokinetic studies (49).

High nanoparticle concentrations are a novel discovery, DNA damage is caused by mitochondrial malfunction and ROS production, and these processes are thought to be the primary causes of cell death (50). Oxidative stress, which is brought on by the production of ROS and the suppression of ATP synthesis, affects the cells. The release of silver ions from the nanoparticles may be another factor contributing to cell death following exposure to metal oxide nanoparticles, which includes apoptosis. Following penetration, metal oxide nanoparticles are thought to produce hydrogen peroxide and other free radicals, which kill cells, and release atomic Ag⁰ and ionic Ag clusters, which render the bacterial enzymes inert. (51).

References

1. Ditta, A.; Arshad, M.; Ibrahim, M. Nanoparticles in Sustainable Agricultural Crop Production: Applications and Perspectives. In *Nanotechnology and Plant Sciences*; Springer: Cham, Switzerland, 2015, 55–75. meter.
2. Dvir T, Timko BP, Kohane DS, Langer R (2011) Nanotechnological strategies for engineering complex tissues. *Nat Nanotechnol* 6:1
3. AD Dwivedi and K Gopal. "Biosynthesis of silver and gold nanoparticles using *Chenopodium album* leaf extract". *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 369.3 (2010): 27-33.
4. Singh T., et al. "Biosynthesized nanoparticles and its implications in agriculture. In: *Biological synthesis of nanoparticles and their applications*". CRC Press (2019): 257-

5. H, Wang D, Li Y (2015) Green chemistry for nanoparticle synthesis. *Chem Soc Rev* 44:5778–5792 274.
6. Aygün A, zdemir S, Gülcan M et al (2020) Synthesis and characterization of Reishi mushroom-mediated green synthesis of silver nanoparticles for the biochemical applications. *J Pharm Biomed Anal* 178:112970. <https://doi.org/10.1016/j.jpba.2019.112970>
7. Patten GS, Abeywardena MY, Bennett LE. Inhibition of angiotensin converting enzyme, angiotensin II receptor blocking and blood pressure lowering bioactivity across plant families. *Crit Rev Food Sci Nutr.* 2013;56:181–214.
8. Bora, L.; Avram, S.; Pavel, I.Z.; Muntean, D.; Liga, S.; Buda, V.; Gurgus, D.; Danciu, C. An Up-To-Date Review Regarding Cutaneous Benefits of *Origanum vulgare* L. Essential Oil. *Antibiotics* 2022, 11, 549. [CrossRef] [PubMed]
9. Khadijeh Abbasi¹, Fahad Said Khan², Muhammad Akram², Rida Zainab², Abid Rashid³, Shamaila Kausar⁴, Bhagyashree Keshwani⁵, Pragnesh Parmar⁶, S Ravichandran^{7*}, RM Madhumitha Sri⁸ and S Suresh Synthesis of Nanoparticles from Plant Extracts, Volume 5 Issue 7 July 2022
10. Behzad Moradi, Saber Abbaszadeh, Somayeh Shahsavari, Mohsen Alizadeh, Fatemeh Beyranvand. The most useful medicinal herbs to treat diabetes. *Res. Ther.* 2018, 5(8):2538-2551.
11. Singh R. Medicinal Plants: A Review. *Journal of Plant Sciences. Special Issue: Medicinal Plants.* Vol. 3, No. 1-1, 2015, pp. 50-55.
12. Dar RA, Shahnawaz M, Qazi PH. Natural product medicines: A literature update. *J Phytopharmacol* 2017;6(6):349-351
13. Raghunath, A. and E. Perumal, Metal oxide nanoparticles as antimicrobial agents: a promise for the future. *International journal of antimicrobial agents*, 2017. 49(2): p. 137-152.
14. ZHANG, X.-F., LIU, Z.-G., SHEN, W. & GURUNATHAN, S. 2016. Silver nanoparticles: synthesis, characterization, properties, applications, and therapeutic approaches. *International journal of molecular sciences*, 17, 1534.
15. LEE, S. H. & JUN, B.-H. 2019. Silver Nanoparticles: Synthesis and application for nanomedicine. *International journal of molecular sciences*, 20, 865
16. Ahmad W, Jaiswal KK, Soni S (2020) Green synthesis of titanium dioxide (TiO₂) nanoparticles by using *Mentha arvensis* leaves extract and its antimicrobial properties. *Inorg Nano-Met Chem.* <https://doi.org/10.1080/24701556.2020.1732419>
17. Sanjay Kumar, Pulak Bhushan, Shantanu Bhattacharya Fabrication of Nanostructures with Bottom-up Approach and Their Utility in Diagnostics, Therapeutics, and Others, 2017 Nov 18:167–19818
18. Siddiqi KS, Husen A (2016) Green synthesis, characterization and uses of palladium/platinum nanoparticles. *Nanoscale Res Lett* 11:482. <https://doi.org/10.1186/s11671-016-1695-z>
19. Ahmed S, Ahmad M, Swami BL, Ikram S (2016a) A review on plants extract mediated synthesis of silver nanoparticles for antimicrobial applications: a green expertise. *J Adv Res* 7:17–28. <https://doi.org/10.1016/j.jare.2015.02.007>
20. Fahimmunisha, B. A., Ishwarya, R., AlSalhi, M. S., Devanesan, S., Govindarajan, M., & Vaseeharan, B. Green fabrication, characterization and antibacterial potential of zinc oxide

nanoparticles using Aloe socotrina leaf extract: A novel drug delivery approach. *Journal of Drug Delivery Science and Technology*, 2020, 55, 101465.

21. Aung, W.W.; Panich, K.; Watthanophas, S.; Naridsirikul, S.; Ponphaiboon, J.; Krongrawa, W.; Kulpicheswanich, P.; Limmatvapirat, S.; Limmatvapirat, C. Preparation of Bioactive De-Chlorophyll Rhein-Rich Senna alata Extract. *Antibiotics* 2023, 12, 181.

22. Saleem K., Khursheed Z., Hano C., Anjum I., Anjum S. Applications of Nanomaterials in Leishmaniasis: A Focus on Recent Advances and Challenges. *Nanomaterials*. 2019;9:1749. doi: 10.3390/nano9121749

23. Wang Y, O'Connor D, Shen Z et al (2019) Green synthesis of nanoparticles for the remediation of contaminated waters and soils: constituents, synthesizing methods, and influencing factors. *J Clean Prod* 226:540–549

24. Rajkumar T, Sapi A, Das G et al (2019) Biosynthesis of silver nanoparticle using extract of Zea mays (corn flour) and investigation of its cytotoxicity effect and radical scavenging potential. *J Photochem Photobiol B Biol* 193:1–7

25. Sekar RP (2013) Formulation and evaluation of azathioprine loaded silver nanopartilces for the treatment of rheumatoid arthritis. *Asian Journal of Biomedical and Pharmaceutical*

26. Chen Y, Fan Z, Zhang Z, Niu W, Li C, Yang N, Zhang H (2018) *Chem Rev* 118:6409

27. Roach KA, Stefaniak AB, Roberts JR (2019) *J Immunotoxicol* 16:87

28. Punnoose, MS, Bijimol, D, Mathew, B. Microwave assisted green synthesis of gold nanoparticles for catalytic degradation of environmental pollutants. *Environ Nanotechnol Monit Manag* 2021;16:100525.

29. Jawed, A, Saxena, V, Pandey, LM. Engineered nanomaterials and their surface functionalization for the removal of heavy metals: a review. *J Water Process Eng* 2020;33:101009.

30. Raghunath, A. and E. Perumal, Metal oxide nanoparticles as antimicrobial agents: a promise for the future. *International journal of antimicrobial agents*, 2017. 49(2): p. 137-152.

31. Gangwar, J., B.K. Gupta, and A.K. Srivastava, Prospects of Emerging Engineered Oxide Nanomaterials and their Applications. *Defence Science Journal*, 2016. 66(4). 61. Singh, R. and H.S. Nalwa,

32. Singh, A., et al., Green synthesis of metallic nanoparticles as effective alternatives to treat antibiotics resistant bacterial infections: A review. *Biotechnology Reports*, 2020. 25: p. e00427.

33. Pugazhendhi, A., et al., Anticancer, antimicrobial and photocatalytic activities of green synthesized magnesium oxide nanoparticles (MgONPs) using aqueous extract of *Sargassum wightii*. *Journal of Photochemistry and Photobiology B: Biology*, 2019. 190: p. 86-97.

34. Karthik, K., et al., Microwave assisted green synthesis of MgO nanorods and their antibacterial and anti-breast cancer activities. *Materials Letters*, 2017. 206: p. 217-220.

35. D. A. M. Kheirallah, L. M. El-Samad, and A. M. AbdelMoneim, "DNA damage and ovarian ultrastructural lesions induced by nickel oxide nano-particles in *Blaps polycresta* (Coleoptera: tenebrionidae)," *Science of the Total Environment*, vol. 753, p. 141743, 2021.

36. M. Enea, E. Pereira, M. Peixoto de Almeida, A. M. Ara'ujo, M. D. L. Bastos, and H. Carmo, "Gold nanoparticles induce oxidative stress and apoptosis in human kidney cells," *Nanomaterials*, vol. 10, no. 5, p. 995, 2020.
37. F. H. Farah, "Nanocarriers as delivery systems for therapeutics agents," *International Journal of Pharmaceutical Sciences and Research*, vol. 10, pp. 3487–3507, 2019.
38. S. Naz, A. Gul, and M. Zia, "Toxicity of copper oxide nanoparticles: a review study," *IET Nanobiotechnology*, vol. 14, no. 1, pp. 1–13, 2020.
39. C. Lopez-Chaves, J. Soto-Alvaredo, M. Montes-Bayon, J. Bettmer, J. Llopis, and C. Sanchez-Gonzalez, "Gold nanoparticles: distribution, bioaccumulation and toxicity. In vitro and in vivo studies," *Nanomedicine: Nanotechnology, Biology and Medicine*, vol. 14, no. 1, pp. 1–12, 2018.
40. Kavasi, R.-M.; Coelho, C.C.; Platania, V.; Quadros, P.A.; Chatzinikolaidou, M. In Vitro Biocompatibility Assessment of NanoHydroxyapatite. *Nanomaterials* 2021, 11, 1152.
41. Narayanaswamy, V.; Al-Omari, I.A.; Kamzin, A.S.; Issa, B.; Tekin, H.O.; Khourshid, H.; Kumar, H.; Mallya, A.; Sambasivam, S.; Obaidat, I.M. Specific Absorption Rate Dependency on the Co²⁺ Distribution and Magnetic Properties in CoxMn1-xFe2O4 Nanoparticles. *Nanomaterials* 2021, 11, 1231
42. Casarrubios, L.; Polo-Montalvo, A.; Serrano, M.C.; Feito, M.J.; Vallet-Regí, M.; Arcos, D.; Portolés, M.T. Effects of IpriflavoneLoaded Mesoporous Nanospheres on the Differentiation of Endothelial Progenitor Cells and Their Modulation by Macrophages. *Nanomaterials* 2021, 11, 1102.
43. Moreno-Vega, A.I.; Gomez-Quintero, T.; Nunez-Anita, R.E.; Acosta-Torres, L.S.; Castano, V. Polymeric and ceramic nanoparticles in biomedical applications. *J. Nanotechnol.* 2012, 2012, 936041.
44. Chatterjee, K.; Sarkar, S.; Rao, K.J.; Paria, S. Core/shell nanoparticles in biomedical applications. *Adv. Colloid Interface Sci.* 2014, 209, 8–39.
45. Singh, P.; Pandit, S.; Mokkalpati, V.R.S.S.; Garg, A.; Ravikumar, V.; Mijakovic, I. Gold nanoparticles in diagnostics and therapeutics for human cancer. *Int. J. Mol. Sci.* 2018, 19, 1979.
46. Blythe, K.L.; Willets, K.A. Super-resolution imaging of fluorophore-labeled DNA bound to gold nanoparticles: A single molecule, single particle approach. *J. Phys. Chem. C* 2016, 120, 803–815.
47. Jyoti Ahlawat, Ritu Hooda, Minakshi Sharma, Vijay Kalra, J. S. Rana & Bhawna Batra. Nanoparticles in Biomedical Applications. *ACS Biomater Sci Eng* 2020 :2294–2303.
48. Polat, O.; Karagoz, A.; Isik, S.; Ozturk, R. Influence of gold nanoparticle architecture on in vitro bioimaging And cellular uptake. *J. Nanopart. Res.* 2014, 16, 2725.
49. Bartosz Klębowski, Joanna Depciuch, Magdalena Parlińska-Wojtan,* and Jarek Baran Applications of Noble Metal-Based Nanoparticles in Medicine. 2018, 19, 4031.
50. Hawraa H. Esmael , Entsar J. Saheb and Salah Abdulla Hasoon, Eco-friendly synthesis of magnesium oxide nanoparticles using Ficus benghalensis leaf extract and it anti- Leishmaniasis activity , *Biochem. Cell. Arch.* Vol. 20, No. 1, pp. 1859-1866, 2020
51. Ismail HH, Hasoon SA, Saheb EJ (2019): The Anti-Leishmaniasis activity of green synthesis silver oxide nanoparticles, *Ann Trop Med & Public Health*; 22(IV):SPe147