

Medicinal Plant Extract Based Nanomaterials, their Synthesis and Applications - A Review

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ABSTRACT

It is a matter of great concern that people do not understand the significance of trees and their benefits. Society must be aware of the importance of trees and their role in human life, wildlife, and the side effects of a lack of trees. It is the reason for today's increasing air pollution because the decrease in the number of trees and lack of trees results in deterioration of the balance of nature. All environmental changes cause several diseases such as stroke, heart disease, chronic obstructive pulmonary disease, respiratory infections, and lung cancer. The medicine we have used has some drawbacks so need to use natural herbs to cure disorders. These natural herbs have magical effects to cure diseases. At the same time, nanoparticles (NPs) have been synthesized using various plant extracts either obtained from leaves, roots, seeds, etc. Plant extract-based NPs are in great trend due to their superior properties and wide range of applicability. This review paper provides a brief knowledge about medicinal plants, Indian medicinal plants used as home remedies, plant extract-based NPs, and their applications as antiviral, anticancer, antibacterial, and antifungal treatment.

Key words: Antibacterial, Anti-cancer, Antiviral, Herbs, Medicinal plants, Nanomaterials.

1. INTRODUCTION

As we know, since ancient times humans and animals are reliant on plants to satisfy their needs. They are using plants to eat tubers, roots, leaves, fruits, branches of plants, and trees. At present, man is cutting trees without thinking to accomplish his selfishness and is not familiar with the great harm he is doing to himself and his nature. We cannot imagine our bare life without plants. There are a number of plants in nature that have outstanding medicinal properties. Our environment is suffering from drastic changes created by men by industrialization and cutting of trees etc. The waste generated by these processes has been introduced into water, air, and soil without any treatment and imparts several kinds of diseases to humans. Hence, we need to focus on search medicinal plants, their origin, and their benefits so that we can use them for our concerns [1,2].

Term Medicinal plant means a plant that is used for herbal medicine and various parts of the plant such as stem, flower, roots, leaf, and stigma have been employed as shown in Figure 1. Medicinal plants are also employed as medicine, food, flavonoid or perfume, etc. At present time, the increase in population, expensive treatments, insufficient supply of drugs, and side effects of several synthetic drugs increase the demands to utilize plant materials as a source of medicines to cure widespread human diseases [3,4].

Treatment with medicinal plants has been measured very safe because there are no side effects and it syncs with nature. It is the wonderful fact about the use of herbal treatments that these are independent of any age group and sexes. *Aloe vera*, Tulsi, Neem, Turmeric, Garlic, and Ginger are medicinal plants that cure several common diseases and are considered home remedies. Medicinal plants are termed as rich resources of constituents that are used in drug development such as pharmacopoeia and synthetic drugs. Furthermore, some plants are measured as significant sources of nutrition and endorsed for their therapeutic values [5,6].

2. HERBS AND THEIR MEDICINAL VALUES

Numerous herbs are employed as blood purifiers to change a long-standing condition by excluding different metabolic toxins. These are also termed "blood cleansers" and increase the immunity of a person by reducing illnesses like fever. There are examples of some medicinal herbs such as Basil, Fennel, Chives, Cilantro, Variegated Lemon Balm, Rosemary, Apple Mint, and Variegated Sage and can be planted in a kitchen garden because these can grow easily, taste, look good, and smell amazing [7]. Some herbs including black cinnamon, myrrh, pepper, aloe, safflower, sandalwood, ginseng, burdock, bayberry, and red clover are utilized to heal wounds, sores, and boils. Figure 2 shows different Indian herbs which are employed as home remedies.

Some Indian herbs are used as home remedy as discussed below:

- Turmeric/Haldi (Botanical name: *Curcuma longa*): Turmeric is yellow and has antibiotic properties which are useful in blocking the growth of harmful microbes, germs, and bacteria and are also used as a home remedy to heal cuts and wounds.
- Aloe Vera/Ghrit Kumari (Botanical Name: *Aloe barbadensis miller*): Aloe Vera is a stem less plant and stores water in its leaves. It is used for treating skin injuries burns, acne, and skin problems. *Aloe Vera* juice is also great for beating indigestion and piles issues.

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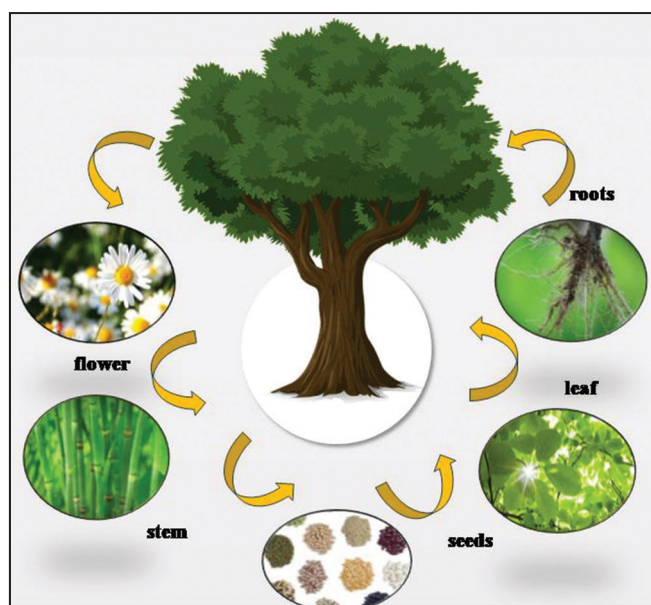


Figure 1: Different parts of plant used in medicine



Figure 2: Indian herbs used as home remedy

- Eucalyptus/Neelgiri (Botanical Name: *Eucalyptus globulus*): The fresh leaves of Eucalyptus are gargled with water or used as a vapor to treat sore throat, cold and bronchitis. Its essential oil is used in relieving nasal congestion, muscle pain, healing wounds, nourishes hair, and asthma problems. It has wide applications such as antiseptic, repellent, pharmaceutical, flavoring, fragrance, and industrial.
- Mint/Pudina (Botanical Name: *Mentha*): Mint is a delicious addition to chutney and mojito. The fresh leaves relieve indigestion and heartburn. Its essential oil is also prized for easing stress, anxiety, and headache.
- Lavender (Botanical Name: *Lavandula*): Lavender oil helps in beating problems including anxiety, stress, depression, and insomnia. It also has antiseptic and anti-inflammatory properties, making it beneficial for burns and bug bites.
- Heart-leaved Moonseed/Giloy (Botanical Name: *Tinospora cordifolia*): Giloy has been used in Ayurveda for ages by folk medicine practitioners. Due to its anti-diabetic, anti-microbial, and anti-oxidant properties, it helps in healing chronic fever, boosts immunity, and improves digestion.
- Bengal quince/Bael (Botanical Name: *Aegle marmelos*): All parts of the Bengal quince tree have been explored medicinally in Ayurveda. Its fruit is a boon for gut health because it helps in digestion and ulcers treatment. Its roots have anti-inflammatory, wound healing, and antidote properties.
- Fennel/Saunf (Botanical Name: *Foeniculum vulgare*): Fennel seeds are high in Vitamin C and useful in treating intestinal gas, bloating, regulating blood pressure, reducing asthma, and loss of appetite. It can be sautéed, roasted, or grilled for softening its flavors.
- Ginger/Adrak (Botanical Name: *Zingiber officinale*): Ginger is an effective home remedy for digestion, flu, sore throat, common cold, and also improves immunity. People consume it in fresh, dried, or powdered form to get other benefits such as weight loss joint pain and stiffness, lower blood sugars, and improved heart disease risk.
- Indian Ginseng/Ashwagandha (Botanical Name: *Withania somnifera*): Ashwagandha is also known as Indian ginseng, poison gooseberry, or winter cherry and it helps in curing several problems including pain, inflammation, insomnia, cancers, Alzheimer's disease, anxiety, and stress. Its leaves, seeds, and fruit are common for treating various ailments and also help in maintaining youth.
- Bacopa/Brahmi (Botanical Name: *Bacopa monnieri*): It is also termed as water hyssop, water hyssop, thyme-leaved Graciela, herb of grace, and Indian pennywort. This ancient herb plays a significant role to improve memory and treat various ailments. Bacopa is beneficial for boosting brain functioning including cognition, learning, memory, and treating hypoglycemia, blood pressure.
- Crepe Ginger/Keu (Botanical Name: *Cheilocostus speciosus*): The rhizome of this herb is useful in healing constipation, headache, leprosy, skin disease, and ear-aches. It goes well in many vegetable recipes in Indian tribal cuisines.
- Rosemary/Gulmehandi (Botanical Name: *Salvia rosmarinus*): Rosemary enhances memory, brain functioning, cognitive functioning, and alertness. The needles such as leaves of rosemary give out a pleasing fragrance and are used in making essential oil too.
- Carom/Ajwain (Botanical Name: *Trachysper mumammi*): Ranging from an ulcer, indigestion, cholesterol to high blood pressure, and carom seeds keep all such problems in check. Packed with Vitamins B, sodium, calcium, iron, and phosphorus.
- Kalanchoe/Pattharchatta (Botanical Name: *Kalanchoe blossfeldiana*): It is also termed as air plant, cathedral bells, life plant, and magic leaf. Leaves of kalanchoe have been boiled in water and used for curing kidney stones and urinary-related problems. In addition, its leaves are also used for relieving insect bites, jaundice, high bp, and chronic cough.
- Basil/Tulsi (Botanical Name: *Ocimum basilicum*): Every Indian home has at least one basil plant due to its numerous health benefits. Holy basil's plant leaves, stems, and seeds have been explored in medicinal preparations. To treat cough and cold, it is boiled with ginger and honey. It also helps to treat anxiety, asthma, flu, stress, fatigue, skin, liver, lung, and oral cancers.
- Butterfly Pea/Shankhpushpi (Botanical Name: *Clitoria ternatea*): The blue tea made from their flowers improves cognitive ability, memory, and relieves anxiety and stress. Thanks to its analgesic properties, blue tea acts as a mood enhancer by calming the mind.

- Chamomile (Botanical Name: *Matricaria chamomilla*): There is no substitute for chamomile for muscle spasms, menstrual disorders, insomnia, and wounds. It can be consumed as tea, and its essential oil is used for aromatherapy.

Some medicinal plants, their common name is discussed in detail in Table 1.

3. NANOMATERIALS BASED ON MEDICINAL PLANTS

From ancient times, plant parts such as bark, stem, root, leaves, and flowers were used in many ways by humans. They were used for food, jute, clothes, juice, medicines, etc. With the onset of scientific studies on plants, chemical constitutions come to light and more sophisticated approaches were made to use plant parts. Nanotechnology is a significant branch of modern research that deals with the synthesis of particle structures ranging from 1 to 100 nm in size. In this size range, all the properties such as chemical, physical, and biological have been changed both individual atoms or molecules and their corresponding bulk. The demand for nanomaterials is growing rapidly and used in a large number of fields such as cosmetics, biomedical, healthcare, food and feed, drug-gene delivery, chemical industries, environment, health, mechanics, optics, electronics, space industries, energy science, catalysis, light emitters, photo-electrochemical applications, and nonlinear optical devices. Some of the initial research related to nanoparticles (NPs) related to plant extract such as *Azadirachta indica* (Neem), *Aloe vera*, and *Emblica officinalis* (amla, Indian Gooseberry) was investigated [8-10]. Following Table 2 lists the different plant-based nanomaterials.

3.1. Green Synthesis of NPs

Metallic NPs such as silver, gold, platinum, zinc, and copper have attained significant attention due to their favorable effects on health and numerous applications in the biomedical fields. Various physical, chemical, and biological methods are generally utilized for fabricating metallic NPs [26]. Evaporation-condensation, sputtering, ball milling, thermal decomposition, micro-emulsion, electrochemical, electrolysis and chemical reduction, etc., are commonly operated physical and chemical fabrication approaches to reduce metallic particles [38]. However, physical and chemical fabrication approaches synthesize stable NPs the required high energy, high radiation, toxic chemicals, and stabilizing agents generally prevent the application characteristics of metal NPs in biomedical fields. The construction of metallic NPs using biological routes has been represented as an effective substitute and green approach to decrease health, cost, and environmental problems [39-41]. The biological routes generally include simple scaling without high pressure, temperature, toxic chemicals, and utilized only environment-friendly resources. In this regard, plants extracts and microorganisms such as yeast, mold, algae, and bacteria have been considered alternative reagents in NPs synthesis. The use of medicinal plants to synthesize NPs is an important branch of biosynthesis routes [42]. Biomolecules present in medicinal plant extract including enzymes, amino acids, vitamins, polysaccharides, and organic acids have been effectively produced size and shape-controlled NPs. Moreover, medicinal plants extract may be responsible for both bio-reduction and capping agents in NPs synthesis. The medicinal plant extract has also been reported to have antidiabetic, antibacterial, anti-inflammatory, antioxidant, and antifungal activities [43,44].

Prasannaraj and Venkatachalam reported the green synthesis of Silver NPs (AgNPs) using bark, leaf, and roots of ten medicinal plants having sizes of 34-98nm and potential antibacterial activities [45]. Tippyawat *et al.* investigated the environmentally friendly synthesis of AgNPs using aloe vera extract [46]. Islam *et al.* reported that *Citrus reticulata*, *Citrus aurantium*, *Citrus sinensis*, and *Citrus grandis*

fruit extracts for the biogenic synthesis of AuNPs have considerable antimicrobial activity [47]. In another report, *Dioscorea bulbifera* tubers were reported to synthesize copper NPs (CuNPs) at 40°C. *D. bulbifera* tubers have antidiabetic antimicrobial, antitumor, and anti-inflammatory properties. The extract was simply prepared by heating the dried fine powder of *D. bulbifera* with deionized water. As-obtained 5 mL *D. bulbifera* extract was treated with 95 ml of 1 mM aqueous $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. Bioreduction of CuSO_4 to Cu^{2+} was examined by measuring the UV-visible absorbance peak [48]. Tahir *et al.* reported the green synthesis of PtNPs using extract of *Taraxacum laevigatum*. The extract was simply prepared in 100 mL of deionized water by heating at 70 °C for 40 min. The as-prepared extract was stirred with a 0.01 M aqueous solution of H_2PtCl_2 . The yellow color H_2PtCl_2 solution transformed to brown within 10 min indicating the enhanced reaction rate of Pt ions reduction [49]. Another herbaceous plant *Ocimum sanctum* also called tulsi has been reported by Ahmad *et al.*, to fabricate AgNPs. Cost-effective, readily accessible tulsi contains antioxidants with many health benefits. The NPs were synthesized at 40°C by mixing 40 mL extract with 0.025 (M) AgNO_3 solutions, respectively. The presence of phytochemical compounds in the extract is the main factor responsible for the reduction of Ag [50].










4. APPLICATIONS

Medicinal plants have been extensively utilized all over the world since ancient times for the treatment of several diseases. Recently, medicinal plants are receiving more attention because they have the potential of providing huge benefits to people, especially in the medical field. The medicinal plant's treatment has the advantage to raise the therapeutic value by decreasing the toxicity and side effects of drugs [51]. Nanotechnology is a new revolution in the field of science due to its wide applications in the scientific, pharmacological, technological, and biomedical sectors. Various physical and chemical routes have been employed to synthesize NPs. NPs can be fabricated by employing several approaches such as chemical, physical, and biological. A physical and chemical method for synthesizing NPs is found to be extremely costly and may cause environmental and biological risks. However, biological or green synthesis of NPs has been attained much attention in the area of research which has numerous applications in healthcare. The medicinal plant-derived Phyto-constituents are used for green synthesis NPs which are more targeted treatment for diseases such as cancer, bacterial, viral, and fungal infection [52]. Figure 3 illustrates the fabrication of metal NPs using medicinal plant extracts and their diverse applications.

The incorporation of medicinal plants with NPs has huge potential for improving the activity and overcoming the problems related to sole NPs and medicinal plants. Furthermore, green synthesis involves the use of medicinal plants for the fabrication of NPs, which is an inexpensive and environment-friendly approach. It has been reported that CuNPs, AgNPs, and gold NPs (AuNPs) displayed tremendous antimicrobial activity against numerous disease-causing pathogens. Biogenic synthesis of NPs from the medicinal plant is quite helpful to overcome the disadvantages related to the traditional herbal drug delivery systems. Metal NPs can be utilized to target the herbal medicine to the specific affected organ which increases the drug delivery, selectivity, efficacy, and safety, thus reducing the medicine dosage. They help to increase the solubility of the herbal drug and concentrate the drug in a particular diseased site which leads to improved efficacy. NPs can transport high concentrations of drugs to a specific diseased body part due to their small particle size and high loading abilities. The small particle size of NPs is also responsible for the rapid dissolution of the drug in the blood due to their high surface area [53].












Table 1: Medicinal plant with their botanical name and uses

Common Name	Botanical Name	Parts Used	Medicinal Use	Images
Amla	<i>Emblica officinalis</i>	Fruit	Vitamin-C, cough, diabetes, cold, laxative, hyper acidity.	
Ashok	<i>Saraca asoca</i>	Bark Flower	Menstrual pain, uterine, disorder, diabetes.	
Aswagandha	<i>Withania somnifera</i>	Root, Leaves	Restorative tonic, stress, nerves disorder, aphrodisiac.	
Bael/Bilva	<i>Aegle marmelous</i>	Fruit, Bark	Diarrhea, dysentery, constipation.	
Bhumi Amla	<i>Phyllanthous amarus</i>	Whole Plant	Anemic, jaundice, dropsy.	
Brahmi	<i>Bacopa monnieri</i>	Whole plant	Nervous, memory enhancer, mental disorder.	
Chiraita	<i>Swertia chiraita</i>	Whole Plant	Skin disease, burning, sensation, fever.	
Gudmar/Madhunasini	<i>Gymnema sylvestre</i>	Leaves	Diabetes, hydrocil, Asthma.	
Guggul	<i>Commiphora wightii</i>	Gum resin	Rheuma tised, arthritis, paralysis, laxative.	



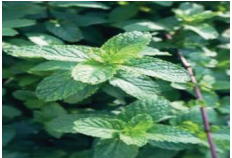






(Contd...)

Table 1: (Continued)

Common Name	Botanical Name	Parts Used	Medicinal Use	Images
Guluchi/Giloe	<i>Tinospora cordifolia</i>	Stem	Gout, pile, general debility, fever, jaundice.	
Calihari/Panchangulia Glori Lily	<i>Gloriosa superba</i>	Seed, tuber	Skin disease, labor pain, abortion, general debility.	
Kalmegh/Bhui Neem	<i>Andrographis paniculata</i>	Whole Plant	Fever, weakness, release of gas.	
Long Peeper/Pippali	<i>Peeper longum</i>	Fruit, Root	Appetizer, enlarged spleen, bronchitis, cold, antidote.	
Makoi	<i>Solanum nigrum</i>	Fruit/whole plant	Dropsy, general debility, diuretic, anti-dysenteric.	
Pashan Bheda/Pathar Chur	<i>Coleus barbatus</i>	Root	Kidney stone, calculus.	
Sandal Wood	<i>Santalum album</i>	Heart wood, oil	Skin disorder, burning, sensation, jaundice, cough.	
Sarpa Gandha	<i>Rauwolfia serpentina</i>	Root	Hyper tension, insomnia.	
Satavari	<i>Asparagus racemosus</i>	Tuber, root	Enhance lactation, general weakness, fatigue, cough.	

(Contd...)

Table 1: (Continued)

Common Name	Botanical Name	Parts Used	Medicinal Use	Images
Senna	<i>Casia augustifolia</i>	Dry Tubers	Rheumatism, general debility tonic, aphrodisiac.	
Tulsi	<i>Ocimum sanctum</i>	Leaves/Seed	Cough, cold, bronchitis, expectorant.	
Pippermint	<i>Mentha piperta</i>	Leaves, Flower, Oil	Digestive, pain killer.	
Henna/Mehdi	<i>Lawsonia inermis</i>	Leaf, Flower, Seed	Burning, steam, anti-inflammatory.	
Gritkumari	<i>Aloe barbadensis miller</i>	Leaves	Laxative, wound healing, skin burns and care, ulcer.	
Sada Bahar	<i>Vinca rosea/ Catharanthus roseus</i>	Whole Plant	Leukemia, hypotensive, antispasmodic, antidot.	
Bhringraj	<i>Eclipta alba</i>	Seed/whole	Anti-inflammatory, digestive, hair tonic.	
Swet Chitrak	<i>Plumbago zeylanica</i>	Root, Rootbark	Appetizer, antibacterial, anticancer.	
Rakta Chitrak	<i>Plumbago indica</i>	Root, Root bar	Dyspepsia, colic, inflammation, cough.	



(Contd...)

Table 1: (Continued)

Common Name	Botanical Name	Parts Used	Medicinal Use	Images
Kochila	<i>Strychnos nuxvomica</i>	Seed	Nervous, paralysis, healing wound.	
Harida	<i>Terminalia chebula</i>	Seed	Trifala, wound ulcer, leprosy, inflammation, cough.	
Baheda	<i>Terminalia bellerica</i>	Seed, Bark	Cough, insomnia, dropsy, vomiting, ulcer, trifala.	
Gokhur	<i>Tribulus terrestris</i>	Whole Plant	Sweet cooling, aphrodisiac, appetizer, digestive, urinary.	
Neem	<i>Azardirchata indica</i>	Rhizome	Sedative, analgesic, epilepsy, hypertensive.	
Anantamool/Sariva	<i>Hemidesmus indicus</i>	Root/Leaf	Appetizer, carminative, aphrodisiac, astringent.	
Bach	<i>Acorus calamus</i>	Rhizome	Sedative, analgesic, epilepsy, hypertensive.	
Vasa	<i>Adhatoda vesica</i>	Whole Plant	Antispasmodic, respiratory, stimulant.	
Nageskar	<i>Mesua ferrea</i>	Bark, Leaf, Flower	Asthma, skin, burning, vomiting, dysentery, piles.	

(Contd...)

Table 1: (Continued)

Common Name	Botanical Name	Parts Used	Medicinal Use	Images
khuskhus	<i>Vetiveria zizanioides</i>	Root	Hyperpiesia, burning, ulcer, skin, vomiting.	
Mandukparni	<i>Centella asiatica</i>	Whole plant	Anti-inflammatory, jaundice, diuretic, diarrhea.	
Kaincha/Creeper Baidanka	<i>Mucuna pruriens</i>	Root, Hair, Seed, Leaf	Nervous, disorder, constipation, nephropathy, strangury, dropsy.	
Dalchini	<i>Cinnamomum zeylanicum</i>	Bark, Oil	Bronchitis, asthma, cardiac, disorder, fever.	
Kurai	<i>Holarrhena antidysentrica</i>	Bark, Seed	Scabies, antipyretic, amoebic dysentery.	
Kantakari/Akranti	<i>Solanum xanthocarpum</i>	Whole Plant, Fruit, Seed	Diuretic, anti-inflammatory, appetizer, stomachic.	

4.1. Antiviral

The coronavirus which is the reason for today's pandemic has developed fear in mankind as a virus grows and spreads rapidly. Millions of people all over the world have lost their lives whereas others lost their family members. Not only coronavirus but other viruses such as HIV, Dengue virus, Influenza virus, Hantavirus, Herpesvirus, Nipah virus, Chikungunya virus, and Ebolavirus also multiply and spread extensively and cause life-threatening diseases. As described in various studies, AgNPs are infectious antiviral agents which may block the viral replication of different types of viruses [54]. Mehmood *et al.* synthesized AgNPs with aqueous extracts of *Syzygium maromaticum* plant (clove). At higher concentrations, these green AgNPs have been shown significant antiviral activity against the Newcastle Viral Disease [55]. Sreekanth *et al.* described the antiviral activity of Panax ginseng roots extracted AgNPs. They investigated antiviral activity using sulforhodamine B assay against influenza virus [56]. In another work, Yugandhar *et al.* studied the synthesis of copper oxide NPs using *Syzygium alternifolium* extract and

their antiviral action against Newcastle Disease Virus [57]. Some medicinal plant extract-based NPs and their antiviral action are described in Table 3.

4.2. Anticancer

The treatment of cancer is very complicated because it is necessary to prevent non-cancerous cells from being damaged while targeting the tumor cells. Various methods such as surgery, radiotherapy, and chemotherapy are widely used for the treatment of cancer cells. However, these typical approaches are costly and have shown various side effects [62]. However, nanosized formulations are useful targeted drug therapies to resolve this problem. During this process, only the growing cancerous cells will be focused on cytotoxicity [63]. The medicinal plant's base nanosized formulations have shown significant results for the treatment and diagnosis of chronic diseases such as cancer as shown in Table 4. AgNPs prepared using leaf extract of *Melia azedarach* have shown active anticancer properties against the HeLa cervical cancer cell.

Table 2: Different plant based nanomaterials and their properties

S. No.	Plant Extract	Nanoparticles	Properties	References
1.	<i>Emblica officinalis</i>	ZnFe ₂ O ₄ -RGO	An alternate to traditional luminescent powder for a safe detection and qualitative improvement of latent fingerprints	[11]
2.	<i>Saraca asoca</i>	Activated carbon nanoparticle from dead leaves	Electrode material in the electric double-layer capacitors	[12]
3.	<i>Withania somnifera</i>	Gadolinium III oxide nanocomposite	Anticancer and radio-sensitizing efficacy	[13]
4.	<i>Aegle marmelous</i>	Ag nanoparticles with methanolic extract of fruit	Antimicrobial activity	[14]
5.	<i>Phyllanthous amarus</i>	CuONPs with leaf wxtract	Antibacterial activity	[15]
6.	<i>Swertia chiraita</i>	ZnONPs with stem extract	Antibacterial activity	[16]
7.	<i>Gymnema sylvestre</i>	Nanofibers mats of caprolactone	Effective wound dressing	[17]
8.	<i>Commiphora wightii</i>	AuNPs	Anticancer activity against MCF-7 breast cancer cell	[18]
9.	<i>Tinospora cordifolia</i>	ZnONPs	Treatment of waste water and industrial effluents	[19]
10.	<i>Gloriosa superba</i>	Platinum and Palladium NPs	Anticancer activity	[20]
11.	<i>Andrographis paniculata</i>	ZnONPs	Anti-oxidant, anti-diabetic, and anti-inflammatory properties	[21]
12.	<i>Peeper longum</i>	rGO-CuO NPs	Lower resistance and higher capacitance electrodes	[22]
13.	<i>Solanum nigrum</i>	Chitosen and Polyvinyl composite films	Food packaging applications	[23]
14.	<i>Santalum album</i>	Silica Nanocolumns	Therapeutic agent	[24]
15.	<i>Asparagus racemosus</i>	AgNPs	Green formulation of an antidandruff shampoo	[25]
16.	<i>Acacia arabica</i>	AgNPs	Antimicrobial studies	[26]
17.	<i>pectin</i>	AgNPs	Antibacterial activity	[27]
18.	<i>Santalum album Tender</i>	AgNPs	Antioxidant capacity	[28]
19.	<i>Dictyota bartayresiana</i>	AuNPs	Antifungal activity	[29]
20.	<i>chitosan matrix prepared using Mangifera indica and Chrysophyllum cainito</i>	Silver Nano/Microparticles	Antibacterial activity	[30]
21.	<i>Bacopa monniera</i>	AuNPs	Antibacterial efficacy	[31]
22.	<i>Terminalia chebula</i>	AgNPs	Antimicrobial potential	[32]
23.	<i>Limonia acidissima</i>	AgNPs	Inactivation of pathogenic bacteria	[33]
24.	<i>Sansevieria roxburghiana</i>	AgNPs	Antibacterial activity	[34]
25.	<i>Salacia mulbarica</i>	AgNPs	Antibacterial and ct-DNA damage via releasing of reactive oxygen species	[35]
26.	<i>Rangoon creeper</i>	AgNPs	Antibacterial activity	[36]
27.	<i>Syzygium cumini</i>	AgNPs	Antibacterial activity	[37]

NPs: Nanoparticles, AuNPs: Gold Nanoparticles, AgNPs: Silver Nanoparticles, CuONPs: Copper nanoparticles, ZnONPs: Zinc oxide nanoparticles

Mousavi *et al.* reported the green synthesis of *Artemisia turcomanica* leaf-loaded AgNPs to examine the cytotoxic activity against gastric cancer cells and normal fibroblast cells (L-929) by MTT assay. They also investigate the cytotoxicity of biological and commercial NPs against cancerous cells and it has been concluded that *Artemisia turcomanica* leaf dopped AgNPs may show greater anti-cancer properties than the sole AgNPs [64].

Black bean extract contains phytate and flavonoids which can suppress the multiplication of colon, breast, liver, and prostate cancer cells through apoptosis without disturbing the growth of normal human fibroblast. Copper compounds have similar properties

to arsenic trioxide and have been utilized to treat several diseases as well as cancer for thousands of years. Nagajyothei *et al.* used phaseolus *Vulgaris* extract (Black bean) for the green synthesis of Copper oxide NPs (CuONPs). In their studies, 0.5 and 1 mg/ml of prepared phaseolus *Vulgaris* mediated CuONPs have been used to prevent the development of HeLa cells. The designed green CuO nanomaterials have shown much better anticancerous activity against HeLa cells with negligible side effects [65]. Manju *et al.* fabricated the water-soluble curcumin-mediated AuNPs to treat numerous cancer cell lines such as Hela cells, glioma cells, and Caco cells. The water-soluble conjugate of curcumin has been synthesized with

hyaluronic acid (HA-Cur) and afterward, AuNPs have been prepared by reducing chloroauric acid with HA-Cur. The curcumin-loaded AuNPs have been used in various analytical methods and assessed blood compatibility and cytotoxicity. Blood materials interface studies indicated that the green synthesis of NPs is extremely hem compatible. The HA-Cur AuNPs exhibited significant cytotoxicity which initiated the development of blood compatible curcumin-conjugated AuNPs having improved targeted efficiency against HeLa cells, glioma cells, and Caco cells [66].

4.3. Antibacterial

The utilization of AuNPs and AgNPs continuously increases in microbial application because NPs have the potential to overcome

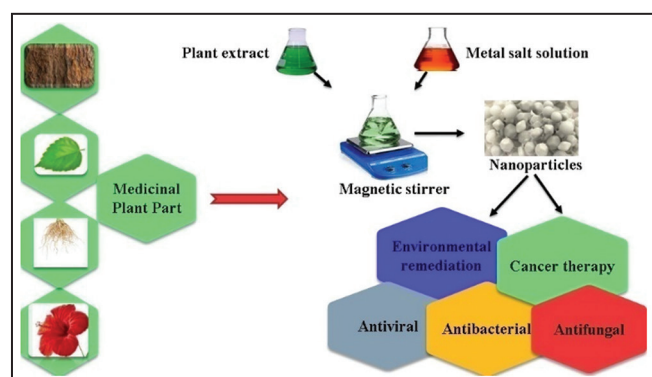


Figure 3: Fabrication of metal nanoparticles through medicinal plant extracts and their possible biomedical and environmental applications

microbial resistance. Numerous NPs have been synthesized to avoid microbial resistance such as nitric oxide-releasing NPs, chitosan NPs, and metallic NPs (Table 5). Among the metallic NPs, the AuNPs and AgNPs prepared through green route synthesis are of great interest [72].

Salayová *et al.* have been successfully prepared AgNPs using five different medicinal plant extracts such as *Brassica nigra* (seeds), *Berberis vulgaris* (root), *Lavandula angustifolia* (leaves), *Capsella bursa-pastoris* (leaves), and *Origanum vulgare* (leaves). In their study, the synthesized AgNPs have been tested against five bacterial strains, that is, *Pseudomonas aeruginosa*, *Listeria monocytogenes*, *Escherichia coli*, *Salmonella enterica* ser. *Typhimurium*, and *Staphylococcus aureus*. It has been found that the green AgNPs at a precursor concentration of 5 mM presented enhanced antimicrobial activity against five bacterial strains [73]. Kumar *et al.* reported the one-step green fabrication route of *Cissus arnotiana* leaf extract mediated CuNPs. The prepared CuNPs have been subjected to evaluate the antibacterial activity against *E. coli*, *Streptococcus* sp., *Rhizobium* sp., and *Klebsiella* sp. The maximum antibacterial property has been detected against *E. coli* due to the electrostatic interactions between CuNPs surfaces and the bacterial cell wall. It has been estimated that an inhibition zone for Gram-negative bacteria *E. coli* was 22.20 ± 0.16 mm at 75 $\mu\text{g/ml}$ [74].

4.4. Antifungal

Metal NPs have attained much attention in the field of biomedical sciences due to their unique physical and chemical properties. Among them, medicinal plant-based AgNPs exhibit a broad spectrum of biocidal activity towards many fungi or viruses as summarized in Table 6. It is estimated that fungi can cause various diseases that range

Table 3: Antiviral action of various medicinal plant extract based nanoparticles

S. No.	Nanoparticles	Plant extract	Virus strain	Refs.
1.	CuO	<i>Syzygium alternifolium</i>	Newcastle Disease Virus	[57]
2.	Ag	<i>Panax ginseng</i>	Influenza A virus Human cervical cancer cell line	[58]
3.	Ag Fe Zn	<i>Citrus limetta</i> peels	Chikungunya virus	[59]
4.	ZnO	<i>Mentha spicata</i>	Tobacco mosaic virus	[60]
5.	Ag	<i>Carica papaya</i>	Dengue virus type 2 viral replication.	[61]

Table 4: Various medicinal plant mediated nanoparticles and their anticancer activity

S. No.	Nanoparticles	Plant extract	Plant Part	Cancer cell	Refs.
1.	CuO	<i>Azadirachta indica</i> <i>Hibiscus rosa-sinensis</i> <i>Murraya koenigii</i> <i>Moringa oleifera</i> <i>Tamarindus indica</i>	Leaf	Human breast (MCF-7) cell Cervical (HeLa) cell Epithelioma (Hep-2) cell Lung (A549) cell One normal human dermal fibroblast cell line	[67]
2.	Ag Au	<i>Indigofera tinctoria</i>	Leaf	Lung cancer cell line	[68]
3.	Zno	<i>Costus pictus</i> D. Don	Leaf	Dalton's lymphoma ascites cells	[69]
4.	Ag	<i>Taraxacum officinale</i> <i>Melia dubia</i>	Leaf	Human breast cancer (KB) cell line	[70]
5.	Ag	<i>Taraxacum officinale</i>	Leaf	Human liver cancer cells (HepG2)	[71]

Table 5: Antibacterial activities of fabricated Au nanoparticles from various plants extract

S. No.	Plant extract	Plant parts	Zones of inhibition (mm)	Bacterial strains	Refs.
1.	<i>Pergularia daemia</i>	Leaf	16–17	<i>S. aureus</i> , <i>P. aeruginosa</i> , <i>E. coli</i>	[74]
2.	<i>Crinum latifolium</i>	Leaf	0.00	<i>E. coli</i> , <i>Agrobacterium tumefaciens</i> , <i>Bacillus subtilis</i> and <i>S. aureus</i>	[75]
3.	<i>Azadirachta indica</i>	Flower	6–16	<i>S. aureus</i> , <i>P. aeruginosa</i> and <i>K. pneumoniae</i>	[6]
4.	<i>Citrus sinensis</i>	Peel	9–12	<i>S. aureus</i> , <i>P. aeruginosa</i> and <i>K. pneumoniae</i>	[76]
5.	<i>Abutilum indicum</i>	Bark	6–9	<i>Bacillus</i> sp. and <i>Streptococcus</i> sp	[77]

S. aureus: *Staphylococcus aureus*, *P. aeruginosa*: *Pseudomonas aeruginosa*, *E. coli*: *Escherichia coli*, *K. pneumoniae*: *Klebsiella pneumoniae*

Table 6: Antifungal activity of various medicinal plant incorporated Ag nanoparticles

S. No.	Plant extract	Plant parts	Fungal species	Refs.
1.	<i>Tropaeolum majus</i>	Leaf	<i>Penicillium notatum</i>	[81]
2.	<i>Boswellia ovalifoliolata</i> and <i>Shorea tumbuggaia</i>	Bark	<i>Aspergillus</i> , <i>Fusarium</i> , <i>Curvularia</i> and <i>Rhizopus</i>	[82]
3.	<i>Svensonia hyderabadensis</i>	stem	<i>Aspergillus</i> , <i>Fusarium</i> , <i>Curvularia</i> and <i>Rhizopus</i>	[83]
4.	<i>Phyllanthus urinaria</i> , <i>Pouzolzia zeylanica</i> and <i>Scoparia dulcis</i>	Leaf	<i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , and <i>Fusarium oxysporum</i>	[84]
5.	<i>Althaea officinalis</i>	Flower	<i>Aspergillus flavus</i> and <i>Penicillium chrysogenum</i>	[85]
	<i>Thymus vulgaris</i>	Leaf		
	<i>Mentha pulegium</i>			

from superficial to deep tissue, life-threatening systemic contagions [78]. Medda *et al.* evaluated the antifungal properties of AgNPs by using *Aloe vera* leaf extract. *Aloe vera* leaf extract incorporated with AgNPs has shown remarkable potential for controlling pathogenic fungus. The biogenic AgNPs exhibited antifungal activity against *Aspergillus* sp. and *Rhizopus* sp. The maximum inhibition zone for *Aspergillus* sp. was obtained at 100 μ L of 1 M AgNPs [79]. Jayaseelan *et al.* prepared AuNPs by using *Abelmoschus esculentus* seeds extract to study its antifungal activity [80].

The antifungal activity of AuNPs has studied pathogenic strains of *Puccinia graminis* (17 mm), *A. flavus* (16 mm), *Aspergillus niger* (15 mm), and *C. albicans* (18 mm). In their investigation, AuNPs at different concentrations, that is, 10, 20, 30, 40, and 50 l were used for the evaluation of the inhibition zone. The highest zone of inhibition was detected in the AuNPs (50 mm) against *P. graminis* (17 mm) and *C. albicans* (18 mm) [80].

4.5. Others

Medicinal plant based metal NPs have been the preferred choice of researchers for environmental application such as heavy metals, pharmaceutical effluents, and textile dyes degradation. Huge amounts of organic and inorganic pollutants are produced every year. The use of medicinal plant extracts in the fabrication of metallic NPs is simple, rapid, environment-friendly, non-pathogenic, and economical approach [86]. Francis *et al.* investigated the removal efficiency of medicinal plant based AuNPs and AgNPs for rhodamine B and methyl orange. They synthesized Ag and Au NPs using *Mussaenda glabrata* leaf through microwave assistance. In their studies, AuNPs - *M. glabrata* (5 μ g/mL) and AgNPs - *M. glabrata* (0.02 mg/mL) exhibited complete removal of rhodamine B under 5 and 9 min while methyl orange under 4 and 7 min [87]. Nemati *et al.* discussed the potential usage of *Rheum turkestanicum* mediated zinc oxide NPs (ZnONPs) as catalyst for remediation of methylene blue (MB). The studies highlighted that *Rheum turkestanicum* - ZnONPs have shown 100% removal of MB within a period of 60 min [88].

5. CONCLUSION AND FUTURE OUTLOOK

In modern era, nanomaterials synthesized using plant extracts are in great demand. These NPs have tremendous applications as anti-fungal, anti-cancer, antibacterial, and wastewater treatment. This is the greener approach that we have used for the synthesis of these materials. Some medicinal plants are termed as natural herb and have several health benefits. One of them is discussed in detail in this paper and can be used as home remedy. Scientists are focusing on the synthesis of nanomaterials using different plant extracts. The value of plants and their importance should be clear to each and every one to preserve our environment. These NP's has been used for the removal of toxic pollutants such as dyes, phenol, and heavy metals from the wastewater obtained from industrial effluents. As we can say, this approach opens new doors to researchers to use plants to get solution for different environmental and health problems.

Moreover, metallic NPs of controlled size and shape are also fabricated in huge amounts by greener approach. The stability and reduction potent of NPs are mainly ascribed to bioactive molecules present in biological resources. However, medicinal plant extracts are more valuable than other biological resources. Using medicinal plant sources for NPs synthesis can open novel prospects in future. Therefore, future research is needed to explore the exact mechanism involved in the bio-reduction process. After exploration, it will transform the synthesis of NPs on both laboratory and commercial scale.

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