

REVIEW OPEN ACCESS

Green Synthesis of Nano-Sized Metal Oxides (Ag_2O , CuO , ZnO , MgO , CaO , and TiO_2) Using Plant Extract for a Sustainable Environment

Sanjana Afrin Disha^{1,2} | Md. Sahadat Hossain¹  | Md. Lawshan Habib² | Samina Ahmed¹

¹Institute of Glass & Ceramic Research and Testing, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh | ²Department of Applied Chemistry and Chemical Engineering, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalganj, Bangladesh

Correspondence: Md. Sahadat Hossain (saz8455@gmail.com) | Samina Ahmed (shanta_samina@yahoo.com)

Received: 20 June 2024 | **Revised:** 5 January 2025 | **Accepted:** 10 February 2025

Funding: This study received no particular grants from public, commercial, or non-profit funding entities.

Keywords: FT-IR | green synthesis | metal oxide | nanoparticle | particle size

ABSTRACT

The demand for green synthesis of metal oxide nanomaterials is increasing tremendously to achieve sustainable development goals and for a clean environment. Simultaneously, metal oxides hold significant importance across various fields, such as catalysis, semiconductors, ceramics, photocatalysis, sensors, medicine, and energy storage, and so forth. The green synthesis process eliminates the use of toxic chemicals in the synthesis process. Different natural solvents (plant extracts) are widely utilized to synthesize metal oxides while maintaining a green environment. The extensively used plant extracts are *Lawsonia inermis*, *Centella asiatica*, *Azadirachta indica*, *Moringa olifera*, *Papaya leaves*, *Paeonia emodi*, *Pavetta indica*, *Cyathea nilgiriensis*, *Callistemon lanceolatus*, *Rhaamnus virgata*, *Daphena alpina*, *Zephyranthes rosea*, *Common hops*, *Gloriosa superba*, *Thymus vulgaris*, *Ixoro coccinea*, *Cassia auriculata*, *Lanata camara*, and so forth, for green synthesis of Ag_2O , CuO , ZnO , MgO , CaO , and TiO_2 nanoparticles (NPs). The synthesis process and the reaction parameters are very crucial for tuning the properties of nanomaterials. In this review, the synthesis process using plant extract is explored along with the reaction parameter's effects on the morphology of the final product. And Fourier Transform Infrared (FTIR) spectroscopy was evaluated for the metal oxides to show the importance of FTIR in inorganic compound analysis.

1 | Introduction

Nanomaterials have numerous practical applications, ranging from electronics and medicine to environmental remediation [1, 2]. A nanometer can be visualized by imagining a line which ranges from 1 to 100 nm [3, 4, 5]. Richard Adolf Zsigmondy first used the term nanometer in 1914 where “Nano” was driven from the Greek term “Dwarf” meaning “A billionth.” Thus, one

billionth of a meter is known as one nanometer. Moreover, due to size reduction, nanoparticles (NPs) at nanoscale become more crucial [6, 7]. Nanomaterials can be manufactured using physical methods including laser ablation [8, 9], pyrolysis, sputtering [10], arc discharge [11], and evaporation [12], as well as chemical methods like sol-gel process [13], CVD [14, 15], colloidal approach [16, 17], and spray pyrolysis [7]. NPs can be synthesized based on these categories also: top-down approaches (mechanical milling

Abbreviations: DW, distilled water; PEG, poly ethylene glycol; BAV, black *Aloe vera*; WAV, white *Aloe vera*; MO, *Moringa olifera*; PB, piper betel; TEOS, tetraethyl orthosilicate; DDI water, double deionized water; TTIP, titanium isopropoxide.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2025 The Author(s). *Nano Select* published by Wiley-VCH GmbH.

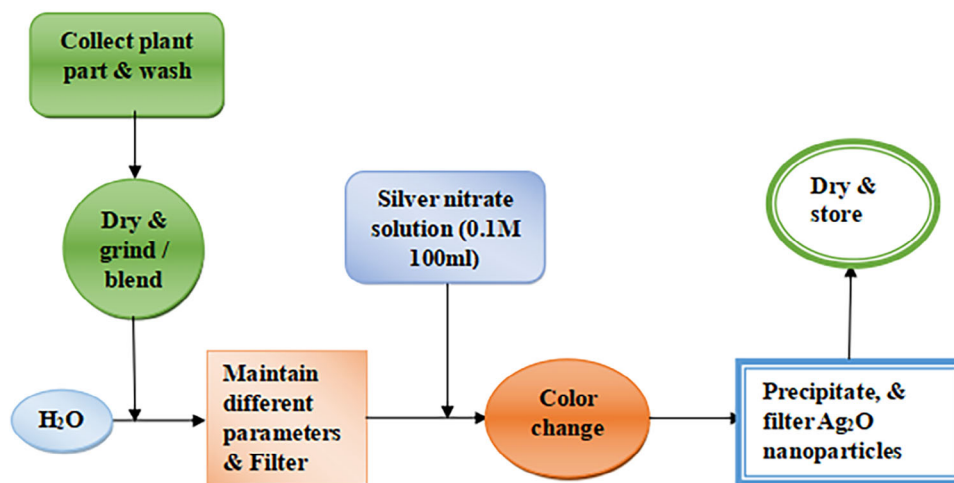


FIGURE 1 | Method of producing Ag₂O from green plants.

[18], mechanochemical processing [19], electroexplosion [20], lithography [20], aerosol based techniques [21], electrospinning technique [22, 23] etc.) and bottom-up approaches (chemical vapor deposition [24, 25], plasma arcing [26], wet chemical methods [27, 28], solvothermal synthesis [29], reverse micelle [30], sol-gel [31]). Nanomaterials can also be synthesized from membrane-based process [32] and green synthesis method [33, 34].

Metal oxide NPs can be synthesized through solution-based [35], vapor state [36, 37], and biological methods [38–40]. When contemplating solution-based synthesis of nano metal oxide, the following methods are commonly used: sonochemistry [41, 42], co-precipitation [43, 44], solvothermal [45], sol-gel [46], microwave-assisted [47–49], and microemulsion [50, 51]. Aside from these approaches, laser ablation [52], chemical vapor based methods [53], and combustion [54] are commonly utilized for vapor based procedures. Finally, biosynthesis [55, 56] is used for a variety of objectives.

Plant extracts, rich in biomolecules, are extracted from medicinal plants mostly using methods like filtration, soxhlet, and serial exhaustive methods with various solvents. Optimal extraction requires solvents of different polarities. Ethyl acetate, hexane, dichloromethane, chloroform, acetone, butanol, or their proper combinations are suggested for effective antimicrobial results [57]. Plant extracts are used in various purposes, such as: improving animal productivity [58], potential mosquito larvicides [59], medicinal cases [60, 61], synthesis of carbon nanotube [62], corrosion inhibitors [63], and so forth.

While considering metal oxide synthesis, green technology [64] is used for such following important purposes like waste prevention, renewability, derivatization steps reduction, degradability, safety concern, use of common solvents, maximum product yield, and low toxicity of used chemicals and yield product [65]. There are lots of beneficial properties of using plant extract, these are: fragrance, antioxidant properties, skin whitening ability, anti-inflammatory properties, wound healing ability, antimicrobial activity, and so forth [66]. Besides this, various plant extract methods are useful for not only giv-

ing huge toxic products but also manufacturing safe quantity [67].

In this review, green synthesis and characterization of different metal oxides such as Ag₂O, CuO, ZnO, MgO, CaO, and TiO₂ NPs were explored based on the green synthesis process where different types of plant extract were used.

2 | Ag₂O Nanoparticle Synthesis

Ag₂O is one of the most important metal oxides for its versatile applications. In general, for the green synthesis of the metal oxide, collected plant parts need to be washed and then dried in sunlight. Dried plant part weighing 1–20 g is then grinded and mixed with a sufficient amount of water (generally 100–250 mL DW) with suitable parameters such as: pH range of 4.2–10, temperature range 4–80°C and time span of 5 min–10 days. Then the solution is filtered sometimes after centrifuging at 3000–5000 rpm and then cooled at room temperature in a place. For example, 100 mL of DI water was used to dissolve 0.1 M AgNO₃, which was added as a precursor to the plant extract at 80°C–160°C for 60 min. Finally, the metal oxide nanoparticle was obtained at color change, which was then dried (60–1100°C, 2 h) and preserved either at room temperatures or less than 5°C [68–80]. A general schematic flowchart is visualized in Figure 1. Different plant extracts can be used to synthesize Ag₂O NPs which are given in the following section. Table 1 registers the synthesis conditions and size of Ag₂O NPs [81], whereas Table 2 represents the peaks for functional groups of green synthesized nanoparticles.

2.1 | *Crocus sativus* (Saffron)

Abdalameer et al. used 100 mL of DI water to prepare both 0.1 M AgNO₃ and 1 g of saffron. Saffron solution was put on the magnetic jacket at 60°C for 10 min. The mixture was filtered after centrifuging (4000 rpm for 15 min) and then placed in a cool place. AgNO₃ solution was gradually added to the plant extract with continuous stirring at 80°C, and the temperature

TABLE 1 | Silver metal oxide NPs synthesis using different plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temperature		
Ag ₂ O	AgNO ₃	<i>Lawsonia inermis</i>	—	1 h	75°C	34.7	[83]
			—	24 h	Room temperature	46 ± 5	[33]
			10	2 h	Room temperature	20–100	[69]
			—	1–3 h	37°C	3–30	[92]
	AgNO ₃	<i>Centella Asiatica</i>	—	5–10 min	600 ± 10°C	11–12	[76]
			—	15 min	50°C	20–40	[93]
	AgNO ₃	<i>Callistemon lanceoletus</i>		1–3 h	37°C	3–30	[77]
	AgNO ₃	<i>Zephyranthes rosea</i>	—	30 min	80°C	10–30	[74]
	Si(OC ₂ H ₅) ₄	<i>Azadirachta indica</i>	8	48 h	60°C	< 50	[94]
	AgNO ₃	<i>Lippia citriodora</i>	—	5–10 min	600 ± 10°C	20	[73]
	AgNO ₃	<i>Helleborus odoratus</i>	—	24 h	Room temperature		[73]
	AgNO ₃	<i>Papaya leaves</i>	—	8 h	Room temperature	40	[70]
	AgNO ₃	<i>Paeonia emodi</i>	—	50 min	90°C	38.29	[78]
	AgNO ₃	<i>Cyathea nilgiriensis</i>	—	—	600°C	Below 100	[75]

TABLE 2 | FTIR peaks of green synthesized silver metal oxides.

Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm ⁻¹)		Refs.
		Main peaks	Other peaks	
Ag ₂ O	<i>Lawsonia inermis</i>		670, 2076, 3412, 3495	[33]
		715	3255, 2360, 1647, 3268, 1616, 2342	[83]
		492, 445	3450, 2392, 1035, 2971, 2392, 1652, 1463, 1102, 1049, 806, 694, 445	[69]
	<i>Centella asiatica</i>		2916, 2850, 1730, 1590, 1019, 600	[93]
	<i>Callistemon lanceoletus</i>	588	2918, 2882, 1647, 1489, 1382, 1230, 1105, 970, 850, 721, 626	[77]
	<i>Paeonia emodi</i>	885, 676	3162, 1050	[78]
	<i>Papaya leaves</i>	671	3447, 1634, 2360, 1438	[70]
	<i>Rhamnus virgata</i>	582, 587	973, 983.9, 1091.56, 1101.69, 1585.31, 1523.23, 3424, 3451,	[68]
	<i>Cyathea nilgiriensis</i>	574	3449, 1629, 1383, 823	[86]
	<i>Daphne alpina</i>	886, 665, 525	3544.68, 3530, 3367, 1388, 1521	[72]
	<i>Zephyranthes rosea</i>	—	1622, 1433, 1383, 1024, 882, 826, 3093, 2925, 2854	[74]

was slowly raised to 160°C and left for 60 min. Here, nanoscale formation of silver (Ag/Ag₂O) was confirmed by the color change [82].

2.2 | *Lawsonia inermis* (Henna Leaves)

According to Fayyadh et al., dust-free henna leaves were chopped and dried using air-dry method. Dry leaves were then powdered using a mechanical grinder. Using a hot plate stirrer, 2 g of henna powder was added in 100 mL of DW (pH 4.2) for 1 h at 50°C. Then the henna solution was filtered and stored for further use.

One mole of aqueous AgNO₃ solution was prepared (100 mL DW) at 700 rpm and 75°C for 1 h. To the obtained solution, 100 mL of henna plant extract was slowly added, with continuous stirring and heating at 75°C for 1 h. The appearance of dark brown color confirmed the synthesis of Ag₂O NPs [83]. Whereas, Daghighian et al. used another method, where after adequately drying, the leaves were extracted in powder form and weighted. For 24 h, 10 g powder and 100 mL DW were shaken. After every 20 min, the mixture was immersed in an ultrasonic bath at decreasing pressure, followed by 5 min of radiation microwave on 320 W. It was next filtered, centrifuged, and preserved at 4°C. In 45 mL of extract, 5.28 mL of 0.05 M AgNO₃ solution was combined,

rapidly agitated at 25°C for 2 h, and then refluxed for 6 h at 130°C. To isolate the raw product, DW and C₂H₆O were used to wash, and following centrifugation, accelerate the elimination of any remaining ions and contaminants. Ultimately, Ag₂O was oven dried at 70°C for 1 h [84].

2.3 | *Azadirachta indica* (Neem Leaves)

Neem leaves were collected, washed, and dried to store in the form of powder according to Dorairajan et al., and then 1% of it was used to make a thick plant extract with the required deionized water, followed by both incubation (30 min) and centrifugation (5000 rpm, 30 min) at room temperature. Filtration was the most necessary step and the leftover solution was used for the reduction of silver ions (Ag⁺) to silver NPs (Ag). AgNO₃ (0.17% of 1 M) salt was added as a precursor to the prepared plant extract. In another literature, clean neem leaves were dried for 10 days. Five grams of powdered leaves were taken in 100 mL of DI water, which was stirred for the next 24 h at room temperature and then filtered. Forty-five milliliters of 0.04 mM aqueous AgNO₃ were taken to prepare a solution using 5 mL plant extract, which caused the reduction of Ag⁺ ions. The color change indicated the synthesis of silver NPs [85]. In another similar method reported by Mohanaparameswari et al., 20 g of dust-free neem leaves were boiled (80°C, 20 h) in 100 mL water and then filtered. A 1 × 10⁻¹ M solution was prepared with 1.52 g of AgNO₃. Ten milliliters of plant powder and AgNO₃ solution were stirred for 20 min, which gave a dark brown color. The mixture was centrifuged (3000 rpm for 10 min) to separate the NPs, which were sintered at 1100°C for 3 h [86].

2.4 | *Lippia citriodora* (Lemon Beebrush plant)

According to Wang et al., collected plant leaves were dried (in an autoclave), grind, and then a standard amount was mixed with AgNO₃ in a silica crucible with continuous stirring for 5–10 min (with minimal water presence). The mixture was placed in a muffle furnace at 600 ± 10°C. The reaction ended with a colorless powder [73].

2.5 | *Acorus calamus* (Sweet Flag Rhizomes)

According to Rajagopal et al., 1% of dried plant powder was used to prepare a 100 mL solution, which was centrifuged (5000 rpm, 25°C, 30 min) after incubation for 30 min. The solution was filtered and then used for the reduction of silver ions (Ag⁺) to silver NPs (Ag). One mole AgNO₃ metal ion solution was taken and added to the prepared plant extract [87].

2.6 | *Humulus lupulus* (Common Hops)

According to Rabiei et al., 250 mg of blended waste hops pellet was mixed with 100 mL of 40% C₂H₅OH with continuous stirring for 5–7 min and then filtered after storing it at 4°C for 48 h for maceration. The mixture was concentrated using a rotary evaporator and stored at 4°C. Fixed (1, 2.5, 5, and 10 mM) solutions were prepared using diluted hops extract and 20 mM AgNO₃ and

kept at room temperature for different time periods (0, 2, 4, 6, 8, 10, 12 h) for the synthesis of NPs, which were obtained by centrifugation and finally freeze-dried, giving dry powdered NPs [88].

2.7 | *Aloe barbadensis* (*Aloe vera*)

According to Flores-Lopez and Tamanna et al., the fresh *Aloe vera* leaves were washed and dried at room temperature. Twenty percent of chopped leaves were taken to prepare an extract which was maintained at 80°C for 20 min. The obtained extract was filtered and stored at 5°C until further use [89, 90].

2.8 | *Syngonium podophyllum* Leaf (Arrowhead Plant)

Naaz et al. prepared a solution of 2.5 g of fine powder by constant warming for 30 min and then filtering. AgNO₃ solution (1 L of 1 mM) was prepared with continuous stirring at 25°C temperature and pH~7. A golden yellowish to dark brown color confirmed the formation of silver NPs which were next centrifuged (10 000 rpm for 15 min), washed, and dried at 60°C after aging for 2 h at 25°C [91].

3 | CuO Nanoparticle Synthesis

The desired plant was collected and washed multiple times. Around 2–350 g plant part was then cut to boil at 80°C–90°C for 10–30 min with 80–700 mL DW. This yielded a solution with a colorful texture, which was filtered and then centrifuged at 1500–10000 rpm at 80°C or room temperature for 15 min–6 h. Then only 5 mL of green extract was added with a precursor and the remaining part was stored at 4°C–10°C. The solution was continuously heated and stirred (pH: 7–12, temperature: 30°C–100°C) for 10 min–2 h. This homogeneous solution was precipitated after adding 0.1 M NaOH and then stirred and centrifuged up to 10 000 rpm at room temperature for a maximum of 1 day. C₂H₅OH was also used besides water for multiple washings. Particles were first dried (50°C–70°C, 12–24 h) and then calcined (55°C–800°C for 10 min–6 h), which gives CuO NPs [95–103]. The synthesis process by Abderrhmane et al. [104] is visualized in Figure 2. Table 3 registers the synthesis conditions and size of CuO NPs, whereas Table 4 represents the peaks for functional groups of green synthesized nanoparticles.

3.1 | *C. sativus* (Saffron)

Two grams of fresh saffron flowers were washed, cut, and boiled by Naaz et al. to produce a strong red-colored solution. The solution obtained was filtered and centrifuged to eliminate impurities and stored. In a prepared 2% Cu(CH₃COO)₂ solution, 5 mL of the flower extract was added dropwise to create dark CuO NPs. Continued heating and stirring resulted in a homogeneous solution. Subsequent dropwise addition of 0.1 M NaOH led to black precipitate formation, which was stirred and then

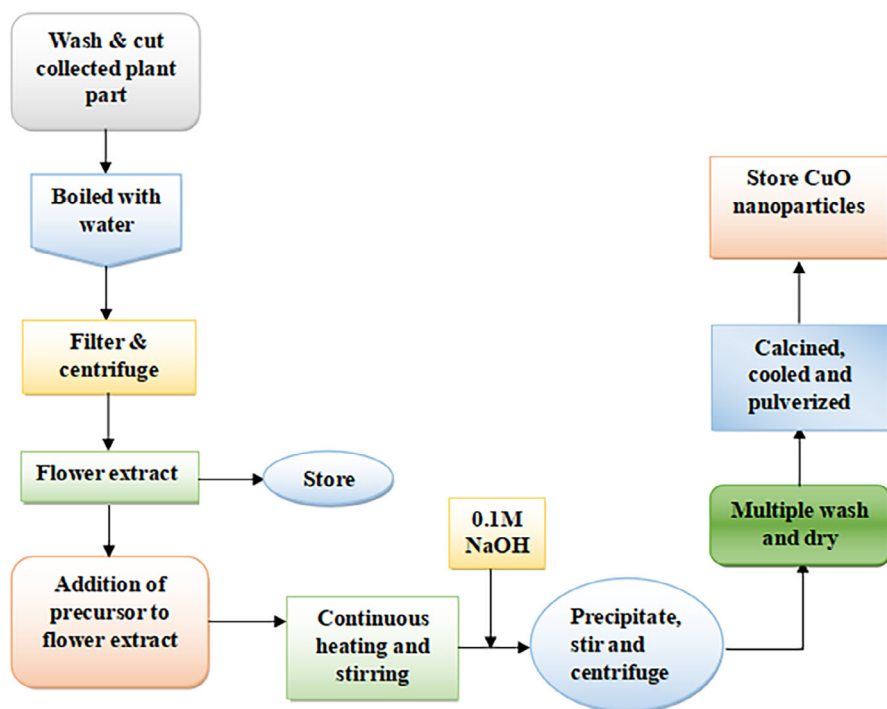


FIGURE 2 | Raw CuO synthesis from different types of green plants.

TABLE 3 | Copper metal oxide synthesis using various plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temperature		
CuO	$\text{Cu}(\text{NO}_3)_2$	<i>Gloriosa superba</i>	—	10 min	$400 \pm 10^\circ\text{C}$	8–17	[95]
	$\text{Cu}(\text{NO}_3)_2$	<i>Pterospermum acerifolium</i>	—	5 min	400°C	212.6–634.4	[98]
	$\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$	<i>Thymus vulgaris</i>	—	5 min	60°C	—	[97]
	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	<i>Ixoro coccinea</i>	—	Overnight	Room temperature	80–110	[110]
	$\text{Cu}(\text{NO}_3)_2$	<i>Aloe vera</i>	—	24 h	$100\text{--}120^\circ\text{C}$	20	[111]
	$\text{Cu}(\text{CO}_2\text{CH}_3)_2 \cdot \text{H}_2\text{O}$	<i>Azadirachta indica</i>	—	2.5 h	55°C	40 ± 5	[112]
	CuSO_4	<i>Cassia auriculata</i>	—	1 h	80°C	23.17	[113]
	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	<i>Momordica charantia</i>	11	Till color changes brown	50°C	61.48 ± 2	[114]
	$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$	<i>Tinospora cordifolia</i>	—	5 min	$400 \pm 10^\circ\text{C}$	6–8	[115]
	$\text{Cu}(\text{CH}_3\text{COO})_2$	<i>Lantana camara</i>	12	2 h	65°C	Below 10	[116]
	CuSO_4	<i>Bauhinia tomentosa</i>	—	4 days	Room temperature	—	[117]
	CuSO_4	<i>Adiantum lunulatum</i>	9	1 h	37°C	6.5 ± 1.5	[118]

centrifuged to remove impurities. The CuO NPs were dried (70°C for a day), calcined (400°C for 15 min), and pulverized after multiple washings. This comprehensive process involved multiple steps, including extraction, synthesis, and purification, to obtain the final CuO NPs for further analysis [91].

3.2 | *Ananus comosus* (Pineapple)

Fardood et al. purchased pineapple (*A. comosus* L. cv. Phuket) from a major fruit market, which was then crushed into pineapple peels (30 g), and 100 mL of DDI water was poured. The

TABLE 4 | FTIR peaks of green synthesized copper metal oxides.

Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm^{-1})		Refs.
		Main peaks	Other peaks	
CuO	<i>Pterospermum acerifolium</i>	3310.7	1700–1000, 1611.2, 1342.3, 1038.0, 9–700	[98]
	<i>Thymus vulgaris</i>	3393, 3406	2926, 1661, 1442, 1300, 1000, 1435, 1622	[97]
	<i>Ixoro coccinea</i>	488, 658	1026, 1479, 1524, 1380–1640, 700, 1300, 2930, 2815	[110]
	<i>Aloe vera</i>	529, 350	1100, 3450, 1600, 2350	[111]
	<i>Cassia auriculata</i>	600, 668	1720, 3385, 1612, 1033, 2922, 1720	[113]
	<i>Momordica charantia</i>	590.4–628.2	459–487.3, 1087.2–1125, 1377.9–1434.6, 1612.8–1668.2, 2071.8, 2700–2954, 3384–3534.3	[114]
	<i>Bauhinia tomentosa</i>	Near 507	3284, 2921, 2850, 1725, 1656, 1521, 1236, 1073	[117]
	<i>Adiantum lunulatum</i>	525, 580	3253, 2948, 2356, 1439, 1538, 1651, 1600, 1240–1280, 1076, 900–700	[74]
	<i>Cordia sebestena</i>	400–600	624, 816, 1072, 1180, 1265	[119]
	<i>Acalypha indica</i>	526	3362, 1675, 1030, 1404	[120]

sample was filtered before being centrifuged at 10 000 rpm for 15 min. Furthermore, 30 g crushed pineapple peels were added to 100 mL water and heated (80°C, 2 h) using the magnetic stirrer heater. The extract was centrifuged and filtered under the same circumstances. CuSO_4 (0.02 M) was dissolved in deionized water to provide a blue solution for copper NPs. Furthermore, it was dissolved in water by 0.1 M $\text{H}(\text{OC}_2\text{H}_4)_n\text{OH}$ 6000 (PEG 6000) and added to an aqueous solution containing a heavily mixed copper salt that changes color from blue to white. CuSO_4 solution with PEG 6000 was newly extracted from pineapple peels and was eventually mixed with 0.1 M NaOH, resulting in a color change from blue to green in cold settings. Furthermore, when stored at 80°C on the water bath, it gives reddish-brown color, which confirm the growth of CuO NPs [105].

3.3 | *L. inermis* (Henna)

Eighty milliliters of water and 1 g Henna powder were cooked by Fardood et al. for 30 min. After centrifugation for 30 min at room temperature, the mixture was filtered before being stored (5°C–10°C). CuO NPs were synthesized utilizing a Henna extract. CuO NPs were made by stirring the mixture of 2 g of $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ and 20 mL of distilled water for the next 10 min. The mixture gave green powder after placement in water bath and continuous stirring at 80°C for 12 h. CuO NPs were achieved after calcining it in air for 4 h at various temperatures (400°C–800°C) [105].

3.4 | *A. barbadensis* (*Aloe vera*) Leaves

Fresh *Aloe vera* leaves were collected, weighed (25 g), washed, crushed, and boiled by Sharma et al. for about 15 min in DW (100 mL) which was then stored after filtering. $\text{Cu}(\text{CH}_3\text{COO})_2$ monohydrate aqueous solutions of 5, 10, and 50 mmol/kg were produced in distilled water. The *Aloe vera* leaf extract was added

to these solutions dropwise (5 mL/min) while constantly stirring at 70°C. After around 15 min, a freshly produced 0.2 mol/kg KOH solution was added to keep the pH 11.5. The presence of CuO NPs gave brownish to black precipitates, which were collected and cleaned with $\text{DW}/\text{C}_2\text{H}_5\text{OH}$ after 4 h of stirring. Next, NPs were oven-dried at 55°C–60°C before storing [106]. In another synthesis method, Gunalan et al. used 25 g of *Aloe vera* leaves to boil (80°C for 5 min) in 100 mL of DI water and filtered the stock of CuO NPs. Five milliliters of *Aloe vera* and 50 mL of $\text{Cu}(\text{NO}_3)_2$ were mixed at 100°C–120°C with constant stirring of 24 h which gave dark crimson in two stages. The mixture of CuO NPs was then centrifuged (10,000 rpm, 10 min, room temperature) and dried in a watch glass, which gave black precipitate for further analysis [106]. Another research publication documented the synthesis of CuO using *Aloe vera*, where a solution of *Aloe vera* (350 g) and water was prepared by cooking for 10 min, maintaining 1:2 ratio, before being filtered and stored. Aloe leaf extracts were diluted by adding 250 mL water. CuSO_4 was taken to dissolve in the aloe extract solution and kept for 7 h at 130°C with steady stirring and then cooled. The achieved black solid product was centrifuged twice (3500 rpm, 20 min) and dried at 120°C, 6 h, which gave the dry precursor as CuO NPs [107].

3.5 | CuO–*A. indica* (Neem)

According to Ahmad et al., fresh neem was shade, dried, and sterilized (0.1% HgCl_2 , 20 s). Fifteen grams of neem powder and 200 mL of double DW were shaken for 6 h at 80°C and 1500 rpm. The extract was separated after agitation and filtered. Finally, 100 mL of pure extract was recovered [99]. A solution of 50 g neem leaves was made by boiling it in 500 mL of DI water and filtered. Hundred milliliter of water was mixed to dissolve $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, and plant extract was added using a magnetic stirrer before boiling at 100°C until aqua blue turned into dark green. It gave yield of black precipitate as CuO NPs after heating at 400°C for 10 min [99].

3.6 | CuO–*Punica granatum* (Pomegranate)

Siddiqui et al. air-dried pomegranate for 4–5 days in the shade and ground it into fine powder. Four hundred milliliters of sterile DI water was used to boil 10 g of powder on a Soxhlet apparatus at 55°C for 30 min, which turns into brown yellow color. The sol-gel process was used to create CuO NPs from the filtered extract. The extract was added dropwise to the prepared $\text{Cu}(\text{CH}_3\text{COO})_2$ solution and gave a brown solution of pH~10 at 60°C. After 4 h of continuous stirring at 80°C, the filtered precipitate was washed using $\text{C}_2\text{H}_5\text{OH}$ and water and then dried at 50°C for 12 h. After 3 h of heating at 300°C it gave black CuO NP powder [96].

3.7 | CuO–*Stigmaphyllon ovatum* (Amazonvine)

Elemike prepared a mixture of 50 mL of amazonvine extract with 250 mL of 2 mM $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. After 4 h of continuous heating at 80°C–90°C, two distinct doses of the Au-CuO nanohybrid were generated by adding 50 mL of the leaf extract to: (i) 250 mL of 1 mM HAuCl_4 and (ii) 250 mL of 2 mM $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ for 1 h at 80°C–90°C. Under the same circumstances, the solution was swirled for another 1 h. The NPs that resulted were centrifuged, dried, and characterized [108].

3.8 | CuO–*C. sativus* (Saffron)

Shashanka et al. boiled 2 g of fresh *C. sativus* (saffron) flowers at 80°C for 15–20 min in 100 mL of DI water until the solution turned a vivid crimson color. After filtering, the solution was centrifuged. A 2% dark green colored $\text{Cu}(\text{CH}_3\text{COO})_2$ solution was prepared from 4 g of $\text{Cu}(\text{CH}_3\text{COOH})_2$ powder with constant stirring for 15 min at 25°C. Five milliliter of red colored extract was added into the copper acetate solution while stirring at 80°C for 10 min, and thus, heating was continued for 10 min. The solution was centrifuged at 7500 rpm for the next 10 min. The yielded NPs were centrifuged after washing properly. Moreover, 0.1 M NaOH solution was added to get a black precipitate, which was agitated, washed, and then again centrifuged with the same parameters. Dark black CuO NPs were oven-dried at 70°C and calcined in an open furnace at 400°C for only 15 min. The yielded NPs were ground and stored for further use [109].

4 | ZnO NP Synthesis

Collected plants were dried, powdered (70°C), sieved, and stored. Another process used was heating (80°C, 15–20 min) collected plants and then crushing them after filtering and storing them at 10°C. The zinc solution was then prepared with a suitable precursor. Then, 2.9 g suitable zinc precursor was added to the plant extract solution while continuously stirring at 25°C–150°C for a few minutes to 6 h. The addition of NaOH solution maintained its pH (~10) while set on an orbital shaker at 100 rpm for 3 h to give zinc composite. The Zinc-containing composite was then centrifuged to 4500–8000 rpm for 10–20 min and also oven dried at 80°C for 2–24 h. In the last step, ZnO NPs were calcined at 400°C for 15 min–1 h [121–130]. The synthesis process [131–139] is

visualized in Figure 3. Table 5 registers the synthesis conditions and size of ZnO NPs whereas Table 6 represents the peaks for functional groups of green synthesized NPs.

4.1 | *A. barbadensis* Miller (*Aloe vera*)

BAV and WAV were dried, powdered, and then 5 g of the product was agitated in 100 mL water at 100 rpm for 15 min at 70°C temperature by Dar et al. before filtering. A solution of 2.9 g $\text{Zn}(\text{CH}_3\text{CO}_2)_2 \cdot 2\text{H}_2\text{O}$ in 50 mL of water was stirred continuously for 1 h at 25°C. After adding 50 mL plant extract, the flask was covered for 1 h by adding NaOH solution. An orbital shaker was maintained at 100 rpm for 3 h. After 1 h, the yellow-colored ZnO nanocomposites formed by centrifuging were dried for 2 h in an oven at 80°C [140]. In another research by Sangeetha et al., 250 g of *Aloe vera* leaves were cooked with water on medium heat, filtered, and crushed. A thin paste of *Aloe vera* gel with a suitable amount of water was preserved at 10°C for future studies. A volume of 250 mL was prepared from *Aloe vera* gel as well as broth. At 150°C temperature, the extract solution was mixed in $\text{Zn}(\text{NO}_3)_2$ under constant stirring for 5–6 h. Several washes gave a white solution, which was centrifuged twice at 4500 rpm for 15 min and later dried at 80°C for 7–8 h [141]. Jose et al. explain a similar type of method where *Aloe vera* was cooked until the color changed to pale yellow and then filtered carefully. After filtering, the leaf extract was transferred to a clean container and refrigerated. 30 mL of 1 M $\text{Zn}(\text{NO}_3)_2$ solution was prepared where 30 mL of leaf extract was then added for 2 min agitation. Moreover, pH~10 was maintained by adding NaOH (5 M) solution. The agitated (1 h) solution was filtered, washed with ethanol and water, and lastly oven dried at 80°C [142]. Similarly, 30 g *Aloe vera* leaf in 100 mL of DI was swirled by Rasli at 60°C for 10 min and then filtered. *Aloe vera* plant extract was mixed with a suitable precursor ($\text{Zn}(\text{NO}_3)_2$) which gave the dry precipitate at 80°C [143].

4.2 | *Terminalia arjuna* Nuts (Arjuna Fruit)

Dar et al. placed 5 g of dried plant material arjuna fruits in 100 mL of distilled water and agitated it (100 rpm) on a hot plate (15 min, 70°C) before filtering. $\text{Zn}(\text{CH}_3\text{CO}_2)_2$ (2.9 g) and water (50 mL) were stirred for 1 h. Adding 50 mL of plant extract, the suspension was left undisturbed for 1 h after mixing NaOH solution. The orbital shaker was set at 100 rpm for 3 h and left for another 30 min, which thoroughly gave yellow-colored ZnO nanocomposite. The ZnO composites were dried for 2 h at 80°C [140].

4.3 | *C. sativus* (Saffron)

Two grams of saffron flower in 100 mL of water was heated by Dar et al. for 20 min at 80°C until it turned into a bright red-colored solution and then filtered. A solution of 0.1 M zinc nitrate hexahydrate was prepared and agitated for 5 min on a magnetic stirrer. Five milliliters of saffron flower extract was mixed into the salt solution dropwise with continuous stirring for 30 min at 80°C until it became yellow. Moreover, 0.1 M NaOH solution was also added dropwise until it showed a pale-yellow

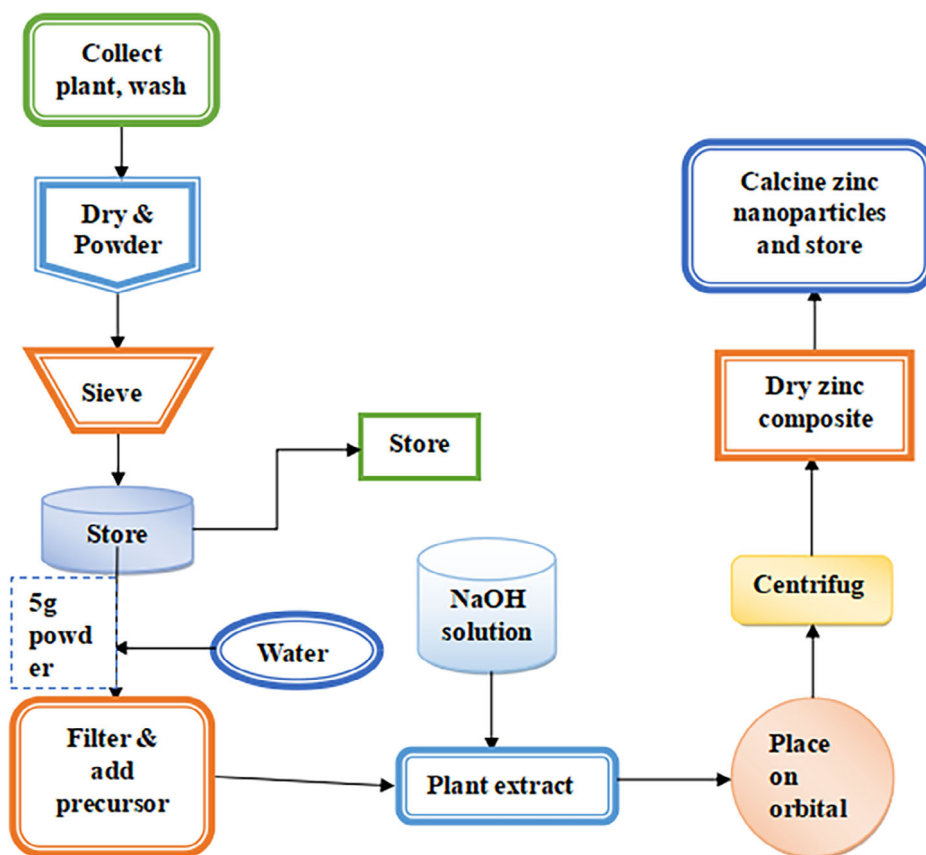


FIGURE 3 | A schematic diagram of zinc oxide extraction from different types of green plant.

TABLE 5 | Zinc metal oxide synthesis using plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temp (°C)		
ZnO	$\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	<i>Thyme leaf</i>	8	3 h	80	39.4–51.86	[121]
	$\text{Zn}(\text{NO}_3)_2$	<i>Solanum nigrum</i>	—	2 h	400	29.79	[147]
	$\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	<i>Azadirachta indica</i>	—	2 h	400	18	[146]
	$\text{Zn}(\text{CH}_3\text{CO}_2)_2 \cdot 2\text{H}_2\text{O}$	<i>Carica papaya</i>	8	2 h	60	50	[127]
	$\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	<i>Calotropis procera</i>	—	3 h	400	24	[148]
	$\text{Zn}(\text{CH}_3\text{CO}_2)_2 \cdot 2\text{H}_2\text{O}$	<i>Laurus nobilis</i>	12	3 h	RT	21.49, 25.25	[125]
	$\text{Zn}(\text{NO}_3)_2$	<i>Lawsonia inermis</i>		48 h	70	—	[124]
	$\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$	<i>Phoenix roebelenii palm</i>		2 h	500	15.6	[149]
	$\text{Zn}(\text{NO}_3)_2$	<i>Euphorbia hirta</i>			60 to 90		[130]
	$\text{Zn}(\text{CH}_3\text{CO}_2)_2$	<i>Syzygium cumini</i>	7	2 h	400	10–12.6	[150]
	$(\text{Zn}(\text{NO}_3)_2)$	<i>Cassia fistula</i>		5 min	400 ± 10	5–15	[151]
	$\text{Zn}(\text{CH}_3\text{CO}_2)_2$	<i>Juglans regia</i>		24 h	60	45–64	[123]

precipitate. Continuous stirring at 80°C for 1–2 min gave complete precipitation. The resulting precipitate was centrifuged for 10 min at 7500 rpm, thus yielding pale yellow/white ZnO NPs, which were dried (70°C overnight) and calcined (400°C, 15 min) before being cooled for further characterization [140].

4.4 | *Acalypha fruticosa* (Birch-Leaved Cat Tail)

Vijayakumar et al. soaked 10 g fresh Birch-Leaved Cat Tail in 100 mL water for agitation (60°C, 20 min) and filtered. To 50 mL of plant extract solution, 0.1 M of $\text{Zn}(\text{CH}_3\text{CO}_2)_2$ was added, and the

TABLE 6 | FTIR peaks of green synthesized zinc metal oxides.

Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm ⁻¹)		Refs.
		Main peaks	Other peaks	
ZnO	<i>Thyme leaf</i>	421	2929, 1521, 1421, 1261, 1056, 1076, 817, 1411, 777, 707, 628	[121]
	<i>Solanum nigrum</i>	400–800, 605	3429, 2924, 1126, 1030, 1404	[147]
	<i>Azadirachta indica</i>	457	3352, 2924, 1647, 1452, 1251, 1045, 663, 1734, 1386, 3739, 3429, 2931, 1637, 1452, 1056, 875	[146]
	<i>Carica papaya</i>	422, 557	1387, 1640, 906, 650	[127]
	<i>Calotropis procera</i>	500–700	1045, 663, 1630, 2106, 3237–3465, 1600, 2900, 3400	[148]
	<i>Laurus nobilis</i>	600, 450	1634, 3300	[125]
	<i>Phoenix roebelenii palm</i>	450	2850, 1627, 1238, 1020, 853, 726, 1300, 1648	[149]
	<i>Euphorbia hirta</i>	513	3438, 2926, 2235, 1384, 1620	[130]
	<i>Syzygium Cumini</i>	400–750	3440, 2949, 1450, 1272, 800	[150]
	<i>Matricaria chamomilla</i>	532, 534, 553, 445, 446, 447	3407, 3417, 3405, 1643, 1651, 1395, 1396, 1061, 1062	[152]

resulting mixture was stirred for 1 h until it yielded a pale yellow solution. After 24 h, a clear precipitate was noticed, which was separated by centrifuge (8000 rpm, 20 min) and then dried at 80°C hot air for 24 h. Lastly, in a muffle furnace, the NPs yielded within 1 h at 400°C [144].

4.5 | *A. indica* (Neem plant)

In a study by Sosail et al., excess aqueous NaOH solution (pH~11) was added to powdered plant material and continuously stirred with appropriate heating for 12 h. For precipitation and filtration, 10 mL of aqueous HCl solution (pH~1) was added to the extract. After pre-extraction with C₄H₈O₂ (5–6 h), 1 M 22 mL of an aqueous solution containing ZnSO₄·7H₂O and a natural surfactant was mixed with 4 M 12 mL NaOH. The mixture was agitated at 25°C before being placed in a microwave oven for 1 min. The resulting ZnO-NP precipitates were dried at room temperature [145]. In another work, Elumailai et al. cooked dried neem leaves in 100 mL of water for 20 min at 60°C, which gave a pale yellow solution. The yellow-colored extract was filtered before being refrigerated. Later, 2 g of Zn(NO₃)₂ crystal, a precursor, was mixed with 20 mL of *A. indica* extract solution and cooked at 60–80°C until a deep yellow paste was revealed. The product was then heated in a furnace (400°C, 2 h), yielding a subsequent amount of ZnO NPs [146].

5 | MgO NP Synthesis

Green plant parts were first dried and then freeze-dried (–40°C, 0.133 mBar) for storage. A 200 mL solution was prepared by combining 5–20 g dried powder, 100 mL water, and 100 mL C₂H₅OH with continuous stirring and heating (450 rpm, room temperature, 24 h) and then filtered. Later, a magnesium precursor was added very slowly in 90 mL plant extract, maintaining some parameters (80°C, 30 min–4 h) and refined at 600°C for 2 h. Moreover, the solution was set in water bath at 50°C, which gave

MgO NPs [153–166]. The synthesis process [167] is visualized in Figure 4. Table 7 registers the synthesis conditions and size of ZnO NPs, whereas Table 8 represents the peaks for functional groups of green synthesized NPs.

5.1 | *A. barbadensis* Miller (*Aloe vera*)

The latex from *Aloe vera* leaves was kept in a bio-dryer for a day and then in a freeze-dryer at –40°C and 0.133 mBar. A solution of 20 g of latex powder, 100 mL DW, and 100 mL ethanol was prepared by Jeevanandam et al. with continuous stirring at 450 rpm for 24 h at room temperature. The extraction purification process gave residues (solid-state) and filtrate (aqueous state), using a water bath (50°C) for MgO nanoparticle synthesis [160]. In another work, Umaralikhan boiled 10 g of *Aloe vera* leaves in 100 mL of water for 5 min at 40°C–50°C and then filtered. Ninety milliliters of leaf extract were added to 1 mM of Mg(NO₃)₂ in 100 mL solution while stirring for 30 min at 80°C until the supernatant evaporated. The final product was pulverized and refined for 2 h at 600°C [162].

5.2 | *A. indica* (Neem)

Five grams of dried neem leaves were boiled and dried for 1 h in 200 mL of DW at 100°C. Five milliliters of leaf extract were heated to 60°C by adding 20 mL of DW. At 80°C, 5 g of Mg(NO₃)₂ was added to the extract with constant stirring for 4 h. The Mg(NO₃)₂ ions were converted to MgO NPs by employing Neem leaf extract, which caused the solution to change color from yellow to yellowish-brown [156].

5.3 | *Psidium guajava* (Guava)

Moorthy et al. boiled 5 g of fresh guava leaves at 40–50°C using 100 mL of water for 5 min and then filtered. In a magnetic stirrer, 90 mL of leaf extract was added to 1 mM 100 mL Mg(NO₃)₂ solution

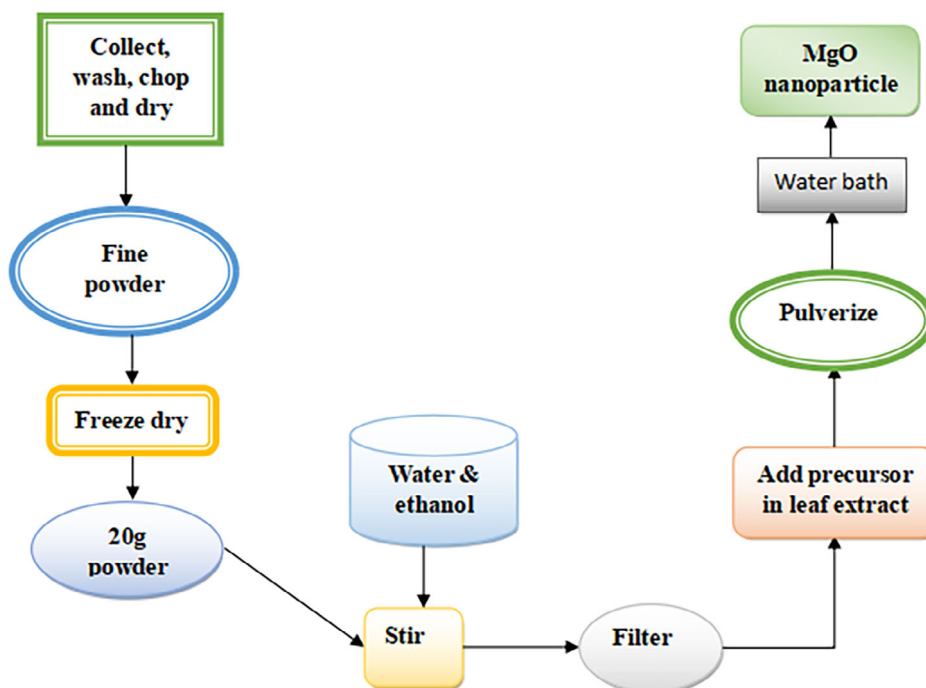


FIGURE 4 | A schematic diagram of MgO NPs from different green plant parts.

TABLE 7 | Synthesis of magnesium metal oxide using plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temperature		
MgO	Mg(NO ₃) ₂ ·6H ₂ O	<i>Costus pictus D. Don</i>	—	—	500°C	50	[151]
	Mg(NO ₃) ₂ ·6H ₂ O	<i>Azadirachta indica</i>	—	4 h	80o C	43	[156]
	Mg(CH ₃ COO) ₂	<i>Lawsonia inermis</i>		4 h	200°C	20, 24	[159]
	NaOH	<i>Ziziphus mauritiana</i>		2 h	450°C	22	[157]
	Mg(NO ₃) ₂ ·6H ₂ O	<i>Dalbergia sissoo</i>	3.2		30 ± 2°C	—	[165]
	MgCl ₂ ·6H ₂ O	<i>Moringa olifera</i>		24 h	70°C	—	[170]
	Mg(NO ₃) ₂ ·6H ₂ O	<i>Camellia sinensis</i>	—	30 min	450°C	80	[165]
	Mg(NO ₃) ₂ ·6H ₂ O	<i>Persimmon</i>	10–12	3 h	400°C	25.6	[153]
	Mg(NO ₃) ₂ ·6H ₂ O	<i>Calotropis gigantea</i>	9 ± 0.2	2 h	450 C	48.3	[155]
	Cu(CH ₃ CO ₂) ₂ , MgSO ₄ , FeCl ₃	<i>Clematis orientalis</i>	—	3 h	350°C	13–53	[171]
		<i>Carica papaya</i>	—	2 h	400°C	20–100	[158]

at 80°C. The yield product was refined at 600°C for 2 h after pulverization [162].

5.4 | *Moringa olifera* (Moringa)

M. oleifera leaves were refluxed by Moorthy et al. at 70°C for 40 min on the heating mantle and then filtered many times. At 25°C, leaf extract, MgCl₂·6H₂O solution, and a few drops of NaOH as a precipitating agent were added at a maintained pH which gave a yellowish tint after 6 h of precipitation. The yellowish solution

was then centrifuged (4000 rpm, 15 min) as well as rinsed with both water and ethanol numerous times to make it contaminant-free. The yield product Mg(OH)₂ was dried at 70°C before being calcined for 3 h upto 700°C, and thus it finally gave white-colored MgO NPs [156].

5.5 | *Camellia sinensis* (Tea Tree)

Akshaykranth et al. cooked 5 g of dried leaves of tea tree with 200 mL of DW for 1 h at 100°C and then filtered the solution.

TABLE 8 | FTIR peaks of green synthesized magnesium metal oxides.

Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm^{-1})		Refs.
		Main peaks	Other peaks	
MgO	<i>Costus pictus D. Don</i>	653.51–825.42	3447.11, 1265.21, 1381.20–1590.22, 1057.70, 2390.15, 1590.22	[151]
	<i>Azadirachta indica</i>	588, 694	3416, 1615, 1481, 3686	[156]
	<i>Lawsonia inermis</i>	524.6	3429.2–3628, 2985, 1582.4, 1132.5	[159]
	<i>Ziziphus mauritiana</i>	584.9	1474.7, 3600–2500	[157]
	<i>Moringa olifera</i>	442, 438	3433, 3452, 1636, 1034	[168]
	<i>Calotropis gigantea</i>	873	3247, 2930, 1575, 1402, 1000–1100, 3690, 3373, 2162, 1462, 1113, 2284, 1977	[155]
	<i>Carica papaya</i>	500–300	3553, 3414.10, 3236.66, 2239.43, 1631.83	[158]
	<i>Chromolaena odorata</i>	608, 404	3409, 1454, 1628, 2347, 1110	[169]
	<i>Eucalyptus globulus</i>	400–800	3319.46, 3316.48, 1982.02, 1947.81, 2162.46, 2170.81, 1538, 1675, 1636, 1627	[160]

The wet chemical approach was used to create MgO-NPs. Ten milliliters of green tea extract were added dropwise into a 0.1 M $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ solution and swirled for 2 h at 80°C. NaOH was utilized to maintain pH~10–12. After 10 min in centrifugation (10 000 rpm), MgO NPs got precipitated. After 8 h of drying (40°C) and 30 min of calcining (450°C), the muffle furnace gave MgO NPs [168].

5.6 | *Tecoma stans* (Yellow bells)

In the study by Khan et al., 10 g of fresh yellow bells flowers (F), barks (B), and leaves (L) were mixed with 100 mL of double DW and filtrated. The combination was centrifuged at 5000 rpm for 20 min, and 90 mL of plant extracts were added with 2 M 10 mL of $\text{Mg}(\text{NO}_3)_2$ solution while stirring at 90°C. One mole NaOH solution was slowly added to the flask for 2 h at 90°C before being centrifuged (5000 rpm) for 15 min. Final material was calcined at 550°C for 6 h to produce MgO NPs [165].

5.7 | *Lawsonia inermis* (Henna Plant)

Akshaykranth et al. placed 15 g of dried henna leaves in 150 mL water on a hot plate at 90°C for 1 h to get a light crimson solution. After filtration, the extract solution was kept in 0.5 M $\text{Mg}(\text{CH}_3\text{COO})_2$ at 80°C until NPs formed. Finally, the formed NP powder was calcined at 200°C for 4 h, which gave grey MgO NPs [159].

5.8 | *Manihot esculenta* (Cassava)

Essien et al. boiled 48 g of dried powder with 250 mL of water for 15 min in a thermostatic water bath and then filtered it. To 50 mL of a 0.1 M solution of $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ kept under a constant stirring condition for 12 h, 250 mL of extract solution was added, and the infusion was centrifuged at 7000 rpm for 10 min. The

precipitate was washed several times. Furthermore, it was oven-dried (70°C, 2 h) and then calcined (500°C, 3 h), which gave MgO NPs after being sonicated at 40°C for 1 h [169].

6 | CaO NP Synthesis

Around 100 g of dried powder was boiled for 30 min and then filtered. 2–120 mL leaf extract was combined with 50 mL precursor and stirred at 50–60°C for 1 h, which showed color change. The solution was filtered after precipitation and washed several times for better results. The solid particles thus obtained were dried and sonicated for around 25–30 min, the product was next passed in a muffle furnace at 400°C–5000°C for 3 h, from which CaO NPs were collected [172–177]. The synthesis process is visualized in Figure 5. Table 9 registers the synthesis conditions and size of CaO NPs, whereas Table 10 represents the peaks for functional groups of green synthesized NPs.

6.1 | *Piper betel* (Betel Plant)

Yoonus et al. added 10 g of dried *Piper betel* leaves to 150 mL of DW and placed them in a microwave at 100 W for 30 min. The filtrate was obtained after the mixture was filtered. Fifty milliliters of 0.1 M aqueous $\text{Ca}(\text{NO}_3)_2$ solution were taken to mix 120 mL of leaf extract with continuous stirring for 1 h, and the color changed to dark brown. The brown precipitate-containing liquid was then sonicated for 30 min before being filtered, washed, and dried. To obtain the CaO NPs, the dried precipitate was next heated at 600°C for 3 h [174].

6.2 | *M. oleifera* (Moringa Leaves)

Jadhav et al. collected MO leaves that were oven-dried at 80°C for 2 h and then ground into powder. Two grams of MO leave powder were cooked using the required amount of DI water for 25 min at

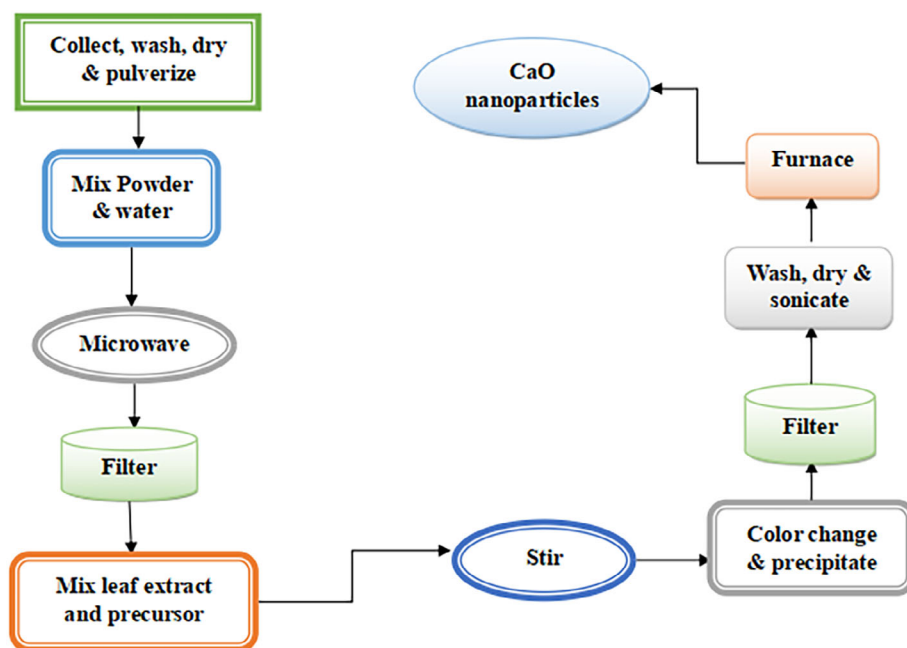


FIGURE 5 | Green synthesis of CaO from different plant extract.

TABLE 9 | Synthesis of calcium metal oxide using plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temperature		
CaO	NaOH	Rhododendron arboretum	—	3 h	500°C	—	[173]
	Ca(NO ₃) ₂ ·H ₂ O	<i>Moringa olifera</i>	—	3 h	400°C	32	[176]
	Ca(NO ₃) ₂	<i>Azadirachta indica</i>	—	Overnight	80°C	100	[179]
	NaOH	<i>Papaya</i>	—		500°C	24	[177]
	NaOH	<i>Broccoli</i>	12	2 h	650°C	32–45	[172]
	—	<i>Piper betel</i>	—	3 h	600°C	24.9	[174]
	CaCl ₂	<i>Cissus quadrangularis</i>	—	1 h	80°C	58	[180]
	NaOH	<i>Cuminumcuminum</i>	—	3 h	450°C		[181]
	—	<i>Punica granatum</i>	—	72 h	80°C	—	[182]

TABLE 10 | FTIR peaks of green synthesized calcium metal oxides.

Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm ⁻¹)		Refs.
		Main peaks	Other peaks	
CaO	Rhododendron arboreum	876, 600	3242, 2514, 2138, 1797, 1635, 1430, 1156, 1074, 876, 600	[173]
	<i>Moringa olifera</i>	437.98	3430, 2918, 1624, 1442, 1062, 2933–2915, 3600–3450, 1620–1655, 1150–1390, 1120–1065	[176]
	Papaya	712	3783, 2926, 1796, 1429	[177]
	Broccoli	868	3635, 3661, 3643, 3438, 2931, 1587, 1591, 1078, 1632, 1017	[172]
	<i>Piper betel</i>	875	1050, 1439, 3461	[174]
	Cuminumcuminum	642.30–567.07	711.73, 873.75, 1396.46, 1795.3, 2364.73, 2513.25, 2926.01	[181]
	<i>Punica granatum</i>	865.9	3735.1, 3643.1, 1419.5, 1068.5, 865.9, 626.8	[182]

60°C and yielded a light brown solution. The solution was filtered and then boiled at 50°C–60°C. A few drops of 2 M NaOH solution were used and 2 g of $\text{Ca}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ ($x = 3, 4, 6$) was boiled after adding the extract solution to get a yellow paste. The mixture was filtered and heated at 400°C for 3 h to achieve the white powder indicating the MO-CaO NPs [176].

6.3 | *Carica papaya* (Papaya Leaves)

Ijaz et al. cooked 100 g papaya leaves in 200 mL of DW for 30 min before being strained. Ten milliliters of $\text{Ca}(\text{NO}_3)_2$ solution and 10 mL of papaya extract were combined while continuously stirring. Thirty minutes later, NaOH was added, which resulted in a white precipitate that was oven-dried for 1 h after filtering it. The dried powders were calcined for 3 h at 500°C [175].

6.4 | *Mentha pipertia* (Peppermint)

Ijaz et al. prepared a solution of leaf extract using DW to filter. Next, 10 cm³ of the filtrate was added to 250 cm³ (1 M) CaCl_2 while continuously stirring for 3 h. The solution turned light green. The mixture was filtered, and the precipitate gave CaO NPs [175].

6.5 | *C. sinensis* (Green Tea Leaves)

In the study by Abukhadra et al., 10 g of green tea leaves were boiled for 30 min. A beaker of 10 mL of CaCl_2 solution and 10 mL of green tea extract were taken, where NaOH was added dropwise while stirring, and it created CaCl_2 white precipitate. The precipitate was oven dried and after that calcined for 3 h at 5000°C [178].

6.6 | *Brassica oleracea* (Broccoli Vegetables)

Osuntokun et al. cooked about 12 g of broccoli leaves at 60°C for 15 min and added them to a 0.1 M 50 mL CaCl_2 solution after cooling the filtered liquid. After that, the infusion was agitated for 40 min before the addition of 2 M NaOH to adjust the pH~12 and was agitated again for the next 2 h. This agitation created a white milky precipitate of $\text{Ca}(\text{OH})_2$, which takes 15 min to complete the centrifugation at 4000 rpm. It almost took 8 h to get CaO NPs in dried form at 90°C [172].

6.7 | *A. indica* (Neem)

Jagadeesh et al. 50 g of powdered neem was taken in 100 mL of water to heat the solution (around 1 h) until the color changed to dark brown. The solution of extract was filtered and stored. 10 min was enough to dissolve the extract solution in 100 mL of DW. Moreover, 5 g of CaCl_2 and 10 mL NaOH were added sequentially at 25°C for 3 h with continual stirring. After filtration, the overnight-held precipitated solution was washed and dried at 80°C overnight. $\text{Ca}(\text{NO}_3)_2$ was completely converted into CaO during drying [179].

7 | TiO_2 NP Synthesis

After collecting the required plant sample, 10–20 g of leaves were taken to prepare a solution of leaves and water. Next, the solution underwent a heating process with following parameters: temperature: 50°C–80°C, and time: 10–40 min. Then the solution was filtered and some precursors (around 5 mL) were added in filtered leaf extract (5 mL) for further processing. A color change appeared after 3 h of continuous stirring at 25°C, which ensured the completion of the first step of synthesis of TiO_2 . Hence, the solution was washed properly using ethyl alcohol after filtering and then dried in air. Next, a muffle furnace was used at 400°C–450°C for 3–24 h to obtain powdered TiO_2 NPs [183–189]. The synthesis process [190] is visualized in Figure 6. Table 11 registers the synthesis conditions and size of CaO NPs, whereas Table 12 represents the peaks for functional groups of green synthesized NPs.

7.1 | *Jatropha curcas* (Purging Nut)

Drummer et al. heated 20 g of fresh leaves in 100 mL of water 80°C for 40 min before filtering them. At 25°C, 80 mL of 0.50 M TiCl_4 and 80 mL of filtered leaf extracts were mixed with continuous stirring, and the color changed to whitish-brown, which signaled the completion of the green synthesis of TiO_2 NPs. At 25°C, the NP solution was stirred with 15 mL of NH_4OH . The precipitate was then filtered and air dried before being calcined at 450°C for 3 h, resulting in the formation of powdered form of TiO_2 NPs [191].

7.2 | *P. betel* (Betel Leaves)

Pushpamalini et al. mixed 20 g fresh betel leaves with 100 mL water, swirled the solution for 30 min at 50°C, and then filtered the extract. Five milliliters of water and 5 mL of $\text{Ti}\{\text{OCH}(\text{CH}_3)_2\}_4$ were added to 25 mL of leaf extract of *P. betel* at 70°C for 3 h. After that, the separated white residue was calcined for 3 h at 400°C, which was TiO_2 NPs [192].

7.3 | *Ocimum tenuiflorum* (Holy Basil)

Pushpamalini et al. mixed 20 g of dried holy basil plant with 100 mL of DW and then filtered it. Twenty-five milliliters of double DW were taken to dilute the mixture of 5 mL of leaf extract and 5 mL of $\text{Ti}\{\text{OCH}(\text{CH}_3)_2\}_4$ at 70°C for 3 h. After chilling it to 30°C, a white residue (separated) was calcined at 400°C [192].

7.4 | *M. oleifera* (Moringa Leaves)

Pushpamalini et al. made a 100 mL solution of 20 g MO plant powder, which takes nearly 30 min at 50°C and then filtered it. Five milliliters of leaf extract, 5 mL $\text{Ti}\{\text{OCH}(\text{CH}_3)_2\}_4$, and 25 mL double DW were mixed in a beaker to make a solution and set at 70°C for 3 h to obtain a white residue. After that, the contents were cooled to room temperature. At 400°C, the white residue was separated and calcined in a furnace for 3 h [192].

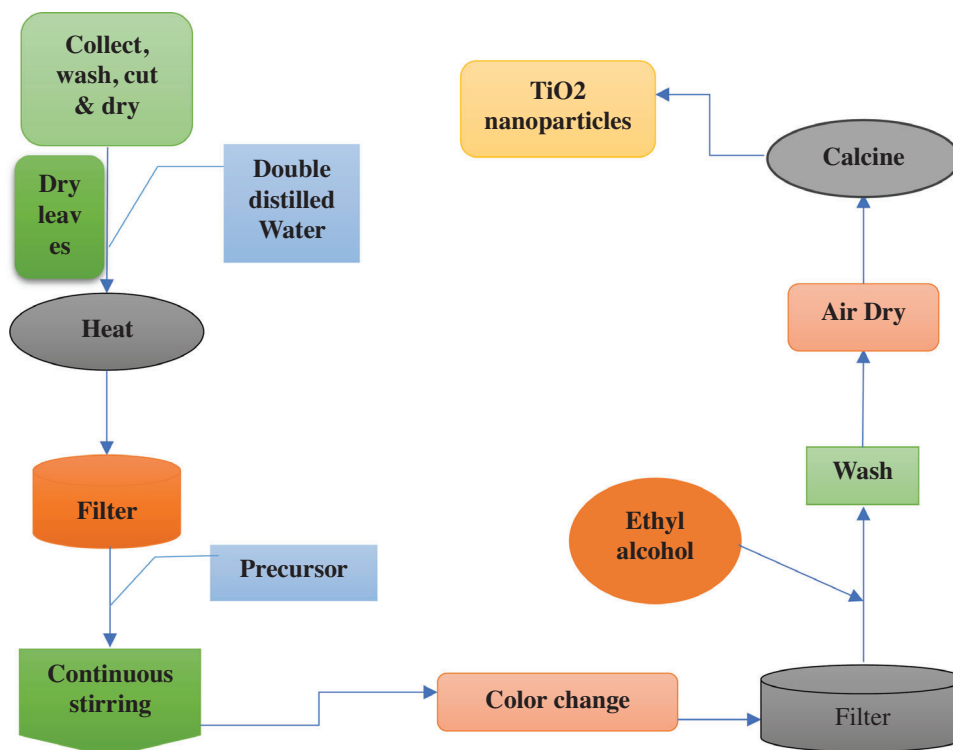


FIGURE 6 | A schematic diagram of production of TiO₂ NPs from various green plants.

TABLE 11 | Synthesis of titanium metal oxide using plant extract.

Metal oxide	Precursor	Plant extract	Synthesis conditions			Size (nm)	Refs.
			pH	Time	Temp.		
TiO ₂	Ti{OCH(CH ₃) ₂ } ₄	<i>Carica papaya</i>	—	—	400°C	15.6	[195]
	Ti{OCH(CH ₃) ₂ } ₄	<i>Mentha arvensis</i>	—	5 h	500°C	20–70	[99]
	TiCl ₄	<i>Jatropha curcas</i>		3 h	450°C	13	[187]
	Ti{OCH(CH ₃) ₂ } ₄	<i>Acorus calamus</i>	7	3 h	600°C	15–40	[189]
	TiO(SO ₄).xH ₂ SO ₄ .yH ₂ O	<i>Trigonella foenum</i>	8	3 h	700°C	20–90	[184]
	Ti{OCH(CH ₃) ₂ } ₄	<i>Phyllanthus niruri</i>	6	24 h	80°C	20	[196]
	Ti{OCH(CH ₃) ₂ } ₄	<i>Jasmine flower</i>	—	2 h	500°C	31–42	[188]
	Ti{OCH(CH ₃) ₂ } ₄	<i>Mentha aquatica</i>	—	2 h	500°C	69	[197]
	TiO ₂	<i>Azadirachta indica</i>	—	1 h	60°C	25–87	[185]
	NH ₄ OH, HCl	<i>Aloe vera</i>	9	4 h	500°C	13–22	[198]
	TiO(OH) ₂	<i>Jatropha curcas</i>	—	12 h	RT	25–100	[199]
	—	<i>Orange peel</i>	7	4 h	500°C	17	[183]

7.5 | *Coriandrum sativum* (Coriander)

Pushpamalini et al. swirled 20 g coriander powder for 30 min at 50°C before being filtered. At 70°C, 25 mL of water, 5 mL of leaf extract, and 5 mL of Ti{OCH(CH₃)₂}₄ were agitated for 3 h. After cooling, the generated white residue was placed for calcining in a furnace for 3 h at 400°C [192].

7.6 | *Coleus aromaticus* (Mexican Mint Leaves)

Akshaykranth et al. combined 10 g pulverized Mexican mint leaf powder with 100 mL DW, and heated the mixture at 60°C for 10 min. At 25°C, 40 mL of the aqueous extract and 160 mL of 1 mM TiO₂ were agitated for 1 day, which led to color change, indicating the creation of TiO₂ NPs [159].

TABLE 12 | FTIR peaks of green synthesized titanium metal oxides.

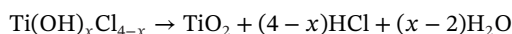
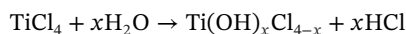
Metal oxide	Plant extract	FTIR peaks (Wavenumber, cm ⁻¹)		Refs.
		Main Peaks	Other peaks	
TiO ₂	<i>Carica papaya</i>	660	1070, 1365, 1544, 1642, 1796–1725, 2926, 1646, 2368	[195]
	<i>Mentha arvensis</i>	596, 977	3371.36, 1634, 1445.26, 1382.63, 1124.82, 1043.94, 800.46, 626.18	[99]
	<i>Jatropha curcas</i>	652	2330, 1757, 681, 1680, 1640, 3400,	[187]
	<i>Acorus calamus</i>	756	3260, 2096, 1583, 1400, 1305, 1066, 1200, 3339, 1627,	[189]
	<i>Trigonella foenum</i>	598, 975	3475, 1630	[184]
	<i>Phyllanthus niruri</i>	662.10	3453.20, 2928.38, 2837.18, 2370.64, 1454.55, 1114.10,	[196]
	<i>Jasmine flowers</i>	900	3709–3712, 1513–1516, 1269–1278, 1057–1055, 460	[188]
	<i>Azadirachta indica</i>	709.62	3581.96, 1166.92, 1091.86	[185]
	<i>Aloe vera</i>	555	1383, 3435, 1631	[198]

7.7 | *Mentha arvensis* (Wild Mint Leaves)

Ahmad et al. produced an ethanolic leaf extract where 25 g of dried leaf powder was mixed in 250 mL of C₂H₅OH at 50°C for 8 h, where a rotary evaporator was used to evaporate ethanol. After 5 h of continuous stirring of 50 mL Ti{OCH(CH₃)₂}₄ and 20 mL ethanolic leaf extract at 50°C, the color changed to whitish brown, indicating the creation of TiO₂ NPs. These NPs were centrifuged at 5000 rpm for 15 min and dried at 500°C within around 5 h [99].

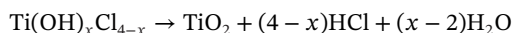
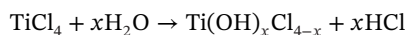
7.8 | *O. tenuiflorum* (Holy Basil)

Bhat et al. cooked 25 g of plant powder for 2 h at 90°C, and 5 h later holy basil solution was filtered. One normality of TiCl₄ solution was combined with 25 mL of holy basil plant leaf extract dropwise for 1 day while preserving pH (5.1–5.3). The TiO₂ NPs were dried overnight at 90°C and then calcined for 5 h at 200°C [193].



7.9 | *Calotropis gigantea* (Giant Calotrope Plant)

Roy et al. dried 25 g of calotrope plant and cooked it for 2 h at 90°C in 100 mL of water, and 5 h later, it was filtered. TiCl₄ solution was made to add in 25 mL of calotrope plant leaf extract and preserved for 1 day maintaining pH (2.2–2.4). The TiO₂ NPs were rinsed multiple times until the pH~7. After overnight drying, TiO₂ NPs were placed for calcining for 5 h at 200°C [194].



7.10 | *Trigonella foenum* (Methi)

Subhapriya et al. swirled dried methi leaves within 20 min using 50 mL of millipore water and then filtered the plant extract. Fifteen milliliters of leaf extract and 0.5 M solution of TiO(SO₄).xH₂SO₄.yH₂O were agitated for 15 min. One mole NaOH was mixed to the agitated solution to maintain pH~8. After precipitation, the products were sintered at 700°C for 3 h to achieve TiO₂ NPs [184].

7.11 | *C. papaya* (Papaya Plant)

Kaur et al. 10 g of leaf powder was taken in an adequate amount of water to heat it for 60 min at 50°C–600°C and then filtered. Under continuous stirring (650 rpm), 40 mL of 0.5 M TTIP was mixed with 40 mL of extract maintaining 1:1 (v/v) ratio. Titanium ions (Ti⁴⁺) were reduced after 30 min. Eight milliliters of NH₃ was added to the mixture dropwise, and washed precipitates were calcined at 400°C, yielding the required NPs [195].

7.12 | *A. barbadensis* (Aloe vera Leaves)

Panneerselvam et al. boiled 25 g of leaves powder in 100 mL water for 2 h and then filtered it. To preserve pH~7, 1.0 N of TiCl₄ solution was mixed drop by drop with continuous stirring. Four hours later, a clear precipitation was noticed and then filtered. After overnight drying at 100°C and calcination for 4 h at 500°C, NPs were obtained [196].

8 | Discussion

Metal oxide NPs, different from metal NPs, widely used for research purposes having the advantage of providing large surface area to volume ratio, low concentration, easily separable after

treatment, and good transport performance with the limiting effect of nanoscale. Metal oxides nanostructures have become an important class of materials with several rich properties and potential applications, especially in microelectronic circuits, coatings against corrosion, sensors, bioimaging, biosensor, piezo-electric devices, drug delivery, fuel cells, tumor ablation, tissue generation, and electrochemical water decomposition field, and so on [200]. Moreover, metal oxides Ag_2O , CuO , ZnO , MgO , CaO , and TiO_2 were selected according to their availability and their potential uses in different sectors such as pigments in paints, environmental remediation, pollutant sensing, plastics, and so on. Hence, these metal oxides also give improved catalytic properties, stability, biocompatibility, photocatalytic and antimicrobial activity, and so on. Several methods got affected while synthesizing NPs such as pH, temperature, particle size, environment, pressure, time, pore size, and proximity. Furthermore, green synthesis uses plants to convert metal ions into metallic atoms, resulting in ecologically beneficial NPs that differ from other conventional synthesis procedures [201]. Using plant extracts in diverse nanoparticle production develops several features such as antidiabetic, anticancer, antiacne, biocompatible, cardio-protective, non-toxic, and antihypertensive. Green synthesis [202] also adds extra benefit to the environment by reducing the discharge of toxic chemicals in the ecosystem [202]. Thus, from the viewpoint of environmental and property tuning, the plant extract-based synthesis process is one of the most chosen for the synthesis of nano-metal oxides. Though plant extracts have some limitations like insolubility in water, unstability, short biological half-life, poor permeability and absorption, contamination issues, and so forth, green synthesis methods are commonly employed in both metal and metal oxide NPs because they are easy, convenient, cost-effective, and ecologically friendly ways that reduce the usage of harmful chemicals [203]. Furthermore, they can reduce and stabilize metal NPs. Plant extracts serve a variety of roles, including antioxidants, antibacterial agents, flavoring agents, coloring agents, enzymes, nutrient enhancers, packaging additives, texturizers, chemical replacements, bio-preservers, inflammatory regulators, and so on. In future, plant extracts can be a great source for the medical (tissue engineering) and environmental sectors [204].

9 | Conclusion

This review examines various syntheses of metal oxides derived from different green plants. The synthesis of metal oxides from green plants is gaining increasing popularity due to their availability, cost-effective methods of synthesis, and ease of handling. This study reviews the synthesis of NPs such as Ag_2O , CuO , ZnO , MgO , CaO , and TiO_2 from several plants, including saffron, *Aloe vera*, neem, henna, and moringa. Among all the methods for synthesizing these metal oxides, the production of Ag_2O and TiO_2 NPs is identified as the simplest. The document covers various types of NPs, noting their sizes: 3–100 nm for Ag_2O , 6.5–634.4 nm for CuO , 13–51 nm for ZnO , 13–100 nm for MgO , 24–100 nm for CaO , and 13–100 nm for TiO_2 . The smallest particle size recorded is 3 nm for Ag_2O , achieved using henna and lemon beebrush plants. The green synthesis method eliminates the necessity of toxic substances during the synthesis process. Additionally, using plant extracts can sometimes enhance various properties. This study highlights the importance of selecting a suitable plant

extraction method to ensure that the solvent can be processed efficiently and reused. FTIR is suggested as one of the most effective techniques for investigating chemical bonds in inorganic compounds and for measuring the wavelengths of absorbed light. This review aims to assist researchers in understanding the process of nano metal oxide synthesis using green solvents and to observe changes in peak positions using the FTIR technique.

Acknowledgments

The authors are grateful to the Bangladesh Council of Scientific and Industrial Research (BCSIR) for their support through the R&D project. Sanjana Afrin Disha wishes to thank the Department of Glass and scientific at BCSIR for allowing her to pursue her scientific interests. Md. Sahadat Hossain acknowledges all sectors involved in this review process.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

If necessary, all of the relevant details will be provided.

References

1. C. N. R. Rao, S. R. C. Vivekchand, K. Biswas, and A. Govindaraj, "Synthesis of Inorganic Nanomaterials," *Dalton Transactions* 34 (2007): 3728–3749, <https://doi.org/10.1039/B708342D>.
2. K. Zhu, Y. Ju, J. Xu, Z. Yang, S. Gao, and Y. Hou, "Magnetic Nanomaterials: Chemical Design, Synthesis, and Potential Applications," *Accounts of Chemical Research* 51 (2018): 404–413, <https://doi.org/10.1021/acs.accounts.7b00407>.
3. N. Baig, I. Kammakakam, and W. Falath, "Nanomaterials: A Review of Synthesis Methods, Properties, Recent Progress, and Challenges," *Materials Advances* 2 (2021): 1821–1871, <https://doi.org/10.1039/D0MA00807A>.
4. J. D. Mackenzie and E. P. Bescher, "Chemical Routes in the Synthesis of Nanomaterials Using the Sol–Gel Process," *Accounts of Chemical Research* 40 (2007): 810–818, <https://doi.org/10.1021/ar7000149>.
5. C.-H. Chang, B. K. Paul, V. T. Remcho, S. Atre, and J. E. Hutchison, "Synthesis and Post-processing of Nanomaterials Using Microreaction Technology," *Journal of Nanoparticle Research* 10 (2008): 965–980, <https://doi.org/10.1007/s11051-007-9355-y>.
6. N. Abid, A. M. Khan, S. Shujait, et al., "Synthesis of Nanomaterials Using Various Top-Down and Bottom-Up Approaches, Influencing Factors, Advantages, and Disadvantages: A Review," *Advances in Colloid and Interface Science* 300 (2022): 102597, <https://doi.org/10.1016/j.cis.2021.102597>.
7. R. Jose Varghese, E. H. M. Sakho, S. Parani, S. Thomas, O. S. Oluwafemi, and J. Wu, "Chapter 3 - Introduction to Nanomaterials: Synthesis and Applications," in *Nanomaterials for Solar Cell Applications*, ed. S. Thomas, E. H. M. Sakho, N. Kalarikkal, S.O. Oluwafemi, and J. Wu, (Elsevier, 2019), 75–95, <https://doi.org/10.1016/B978-0-12-813337-8.00003-5>.
8. J. Zhang, M. Chaker, and D. Ma, "Pulsed Laser Ablation Based Synthesis of Colloidal Metal Nanoparticles for Catalytic Applications," *Journal of Colloid and Interface Science* 489 (2017): 138–149, <https://doi.org/10.1016/j.jcis.2016.07.050>.
9. R. A. Ismail, M. H. Mohsin, A. K. Ali, K. I. Hassoon, and S. Erten-Elä, "Preparation and Characterization of Carbon Nanotubes by Pulsed Laser Ablation in Water for Optoelectronic Application," *Physica E: Low-Dimensional Systems and Nanostructures* 119 (2020): 113997, <https://doi.org/10.1016/j.physe.2020.113997>.

10. H. H. Son, G. H. Seo, U. Jeong, D. Y. Shin, and S. J. Kim, "Capillary Wicking Effect of a Cr-Sputtered Superhydrophilic Surface on Enhancement of Pool Boiling Critical Heat Flux," *International Journal of Heat and Mass Transfer* 113 (2017): 115–128, <https://doi.org/10.1016/j.jheatmasstransfer.2017.05.055>.
11. D. Zhang, K. Ye, Y. Yao, et al., "Controllable Synthesis of Carbon Nanomaterials by Direct Current Arc Discharge From the Inner Wall of the Chamber," *Carbon* 142 (2019): 278–284, <https://doi.org/10.1016/j.carbon.2018.10.062>.
12. Y. Xu, L. Shi, X. Zhang, K. Wong, and Q. Li, "The Electron Beam Irradiation Damage on Nanomaterials Synthesized by Hydrothermal and Thermal Evaporation Methods—An Example of ZnS Nanostructures," *Micron* 42 (2011): 290–298, <https://doi.org/10.1016/j.micron.2010.09.009>.
13. M. Parashar, V. K. Shukla, and R. Singh, "Metal Oxides Nanoparticles via Sol–Gel Method: A Review on Synthesis, Characterization and Applications," *Journal of Materials Science: Materials in Electronics* 31 (2020): 3729–3749, <https://doi.org/10.1007/s10854-020-02994-8>.
14. K. A. Shah and B. A. Tali, "Synthesis of Carbon Nanotubes by Catalytic Chemical Vapour Deposition: A Review on Carbon Sources, Catalysts and Substrates," *Materials Science in Semiconductor Processing* 41 (2016): 67–82, <https://doi.org/10.1016/j.mssp.2015.08.013>.
15. P. Machac, S. Cichon, L. Lapcak, and L. Fekete, "Graphene Prepared by Chemical Vapour Deposition Process," *Graphene Technol* 5 (2020): 9–17, <https://doi.org/10.1007/s41127-019-00029-6>.
16. P. L. Saldanha, V. Lesnyak, and L. Manna, "Large Scale Syntheses of Colloidal Nanomaterials," *Nano Today* 12 (2017): 46–63, <https://doi.org/10.1016/j.nantod.2016.12.001>.
17. W. Baek, H. Chang, M. S. Bootharaju, J. H. Kim, S. Park, and T. Hyeon, "Recent Advances and Prospects in Colloidal Nanomaterials," *JACS Au* 1 (2021): 1849–1859, <https://doi.org/10.1021/jacsau.1c00339>.
18. T. Prasad Yadav, R. Manohar Yadav, and D. P. Singh, "Mechanical Milling: A Top Down Approach for the Synthesis of Nanomaterials and Nanocomposites," *Nanoscience and Nanotechnology* 2 (2012): 22–48, <https://doi.org/10.5923/j.nn.20120203.01>.
19. T. Tsuzuki, "Mechanochemical Synthesis of Metal Oxide Nanoparticles," *Communications Chemistry* 4 (2021): 1–11, <https://doi.org/10.1038/s42004-021-00582-3>.
20. A. A. Tseng, A. Notargiacomo, and T. P. Chen, "Nanofabrication by Scanning Probe Microscope Lithography: A Review," *Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures Processing, Measurement, and Phenomena* 23 (2005): 877–894, <https://doi.org/10.1116/1.1926293>.
21. G. Biskos, V. Vons, C. U. Yurteri, and A. Schmidt-Ott, "Generation and Sizing of Particles for Aerosol-Based Nanotechnology, KONA," *Powder and Particle Journal* 26 (2008): 13–35, <https://doi.org/10.14356/kona.26.2008006>.
22. R. Ostermann, J. Cravillon, C. Weidmann, M. Wiebcke, and B. M. Smarsly, "Metal–Organic Framework Nanofibers via Electrospinning," *Chemical Communications* 47 (2011): 442–444, <https://doi.org/10.1039/C0CC02271C>.
23. P. S. Kumar, J. Sundaramurthy, S. Sundarajan, et al., "Hierarchical Electrospun Nanofibers for Energy Harvesting, Production and Environmental Remediation," *Energy & Environmental Science* 7 (2014): 3192–3222, <https://doi.org/10.1039/C4EE00612G>.
24. Q. Wu, W. Wongwiriyan, J.-H. Park, et al., "In Situ Chemical Vapor Deposition of Graphene and Hexagonal Boron Nitride Heterostructures," *Current Applied Physics* 16 (2016): 1175–1191, <https://doi.org/10.1016/j.cap.2016.04.024>.
25. J. Oarlsson and P. M. Martin, "Chapter 7 - Chemical Vapor Deposition," in *Handbook of Deposition Technologies for Films and Coatings (Third Edition)*, ed. P. M. Martin, (William Andrew Publishing, 2010), 314–363, <https://doi.org/10.1016/B978-0-8155-2031-3.00007-7>.
26. L. N. Mishra, K. Shibata, H. Ito, N. Yugami, and Y. Nishida, "Characterization of Pulsed Discharge Plasma at Atmospheric Pressure," *Surface and Coatings Technology* 201 (2007): 6101–6104, <https://doi.org/10.1016/j.surfcoat.2006.08.126>.
27. S. Thomas, E. H. M. Sakho, N. Kalarikkal, O.S. Oluwafemi, and J. Wu, eds., *Nanomaterials for Solar Cell Applications* (Elsevier, 2019).
28. M. P. Nikolova and M. D. Apostolova, "Advances in Multifunctional Bioactive Coatings for Metallic Bone Implants," *Materials* 16 (2023): 183, <https://doi.org/10.3390/ma16010183>.
29. S. Cao, C. Zhao, T. Han, and L. Peng, "Hydrothermal Synthesis, Characterization and Gas Sensing Properties of the WO₃ Nanofibers," *Materials Letters* 169 (2016): 17–20, <https://doi.org/10.1016/j.matlet.2016.01.053>.
30. J. Zhang, D. D. DesMarteau, S. Zuberi, et al., "Synthesis of the First Difunctional N-Fluoro Perfluoroalkylsulfonilimides, CF₃SO₂NFSO₂(CF₂)_nSO₂NFSO₂CF₃," *Journal of Fluorine Chemistry* 116 (2002): 45–48, [https://doi.org/10.1016/S0022-1139\(02\)00121-5](https://doi.org/10.1016/S0022-1139(02)00121-5).
31. D.-H. Chen and X.-R. He, "Synthesis of Nickel Ferrite Nanoparticles by Sol-Gel Method," *Materials Research Bulletin* 36 (2001): 1369–1377, [https://doi.org/10.1016/S0025-5408\(01\)00620-1](https://doi.org/10.1016/S0025-5408(01)00620-1).
32. C. R. Martin, "Membrane-Based Synthesis of Nanomaterials," *Chemistry of Materials* 8 (1996): 1739–1746, <https://doi.org/10.1021/cm960166s>.
33. V. S. Nandeshwar, S. A. Kalkar, and P. S. Agrawal, "Green Synthesis of Nanoparticles Using Plants as a Bioreactor," *International Journal of Scientific Research in Science and Technology* 9 (2022): 148–156, <https://doi.org/10.32628/IJSRST22933>.
34. C. P. Devatha and A. K. Thalla, "Chapter 7 - Green Synthesis of Nanomaterials," in *Synthesis of Inorganic Nanomaterials*, eds. S. Mohan Bhagyaraj, O.S. Oluwafemi, N. Kalarikkal, and S. Thomas, (Woodhead Publishing, 2018), 169–184, <https://doi.org/10.1016/B978-0-08-101975-7.00007-5>.
35. K. Y. Kumar, H. B. Muralidhara, Y. A. Nayaka, J. Balasubramanyam, and H. Hanumanthappa, "Low-Cost Synthesis of Metal Oxide Nanoparticles and Their Application in Adsorption of Commercial Dye and Heavy Metal Ion in Aqueous Solution," *Powder Technology* 246 (2013): 125–136, <https://doi.org/10.1016/j.powtec.2013.05.017>.
36. J. Ruusunen, M. Ihalainen, T. Koponen, et al., "Controlled Oxidation of Iron Nanoparticles in Chemical Vapour Synthesis," *Journal of Nanoparticle Research* 16 (2014): 2270, <https://doi.org/10.1007/s11051-014-2270-0>.
37. M. S. Chavali and M. P. Nikolova, "Metal Oxide Nanoparticles and Their Applications in Nanotechnology," *SN Applied Sciences* 1 (2019): 607, <https://doi.org/10.1007/s42452-019-0592-3>.
38. J. Jeevanandam, Y. S. Chan, and M. K. Danquah, "Biosynthesis of Metal and Metal Oxide Nanoparticles," *ChemBioEng Reviews* 3 (2016): 55–67, <https://doi.org/10.1002/cben.201500018>.
39. J. Jeevanandam, S. F. Kiew, S. Boakye-Ansah, et al., "Green Approaches for the Synthesis of Metal and Metal Oxide Nanoparticles Using Microbial and Plant Extracts," *Nanoscale* 14 (2022): 2534–2571, <https://doi.org/10.1039/D1NR08144F>.
40. G. M. Nair, T. Sajini, and B. Mathew, "Advanced Green Approaches for Metal and Metal Oxide Nanoparticles Synthesis and Their Environmental Applications," *Talanta Open* 5 (2022): 100080, <https://doi.org/10.1016/j.talo.2021.100080>.
41. J. H. Bang and K. S. Suslick, "Applications of Ultrasound to the Synthesis of Nanostructured Materials," *Advanced Materials* 22 (2010): 1039–1059, <https://doi.org/10.1002/adma.200904093>.
42. S.-H. Jung, E. Oh, K.-H. Lee, et al., "Sonochemical Preparation of Shape-Selective ZnO Nanostructures," *Crystal Growth & Design* 8 (2008): 265–269, <https://doi.org/10.1021/cg070296l>.
43. S. Tazikeh, A. Akbari, A. Talebi, and E. Talebi, "Synthesis and Characterization of Tin Oxide Nanoparticles via the Co-Precipitation

- Method,” *Materials Science - Poland* 32 (2014): 98–101, <https://doi.org/10.2478/s13536-013-0164-y>.
44. M. Mukhtar, L. Munisa, and R. Saleh, “Co-Precipitation Synthesis and Characterization of Nanocrystalline Zinc Oxide Particles Doped With Cu^{2+} Ions,” *Materials Sciences and Applications* 2012 (2012): 543–551, <https://doi.org/10.4236/msa.2012.38077>.
 45. K. Gopalakrishnan, H. M. Joshi, P. Kumar, L. S. Panchakarla, and C. N. R. Rao, “Selectivity in the Photocatalytic Properties of the Composites of TiO_2 Nanoparticles With B- and N-Doped Graphenes,” *Chemical Physics Letters* 511 (2011): 304–308, <https://doi.org/10.1016/j.cplett.2011.06.033>.
 46. S. A. Corr, Y. K. Gun’ko, A. P. Douvalis, M. Venkatesan, R. D. Gunning, and P. D. Nellist, “From Nanocrystals to Nanorods: New Iron Oxide–Silica Nanocomposites From Metallorganic Precursors,” *Journal of Physical Chemistry C* 112 (2008): 1008–1018, <https://doi.org/10.1021/jp076871d>.
 47. A. Roy and J. Bhattacharya, “Microwave-Assisted Synthesis and Characterization of CaO Nanoparticles,” *International Journal of Nanoscience* 10 (2011): 413–418, <https://doi.org/10.1142/S0219581X11008150>.
 48. X. Zheng, S. Wang, L. Wu, and X. Hou, “Microwave-assisted Facile Synthesis of Mono-Dispersed Ba/Ho Co-Doped Nanohydroxyapatite for Potential Application as Binary CT Imaging Contrast Agent,” *Microchemical Journal* 141 (2018): 330–336, <https://doi.org/10.1016/j.microc.2018.05.044>.
 49. M. Baghbanzadeh, L. Carbone, P. D. Cozzoli, and C. O. Kappe, “Microwave-Assisted Synthesis of Colloidal Inorganic Nanocrystals,” *Angewandte Chemie International Edition* 50 (2011): 11312–11359, <https://doi.org/10.1002/anie.201101274>.
 50. M. Sanchez-Dominguez, M. Boutonnet, and C. Solans, “A Novel Approach to Metal and Metal Oxide Nanoparticle Synthesis: The Oil-in-Water Microemulsion Reaction Method,” *Journal of Nanoparticle Research* 11 (2009): 1823–1829, <https://doi.org/10.1007/s11051-009-9660-8>.
 51. C. Solans, P. Izquierdo, J. Nolla, N. Azemar, and M. J. Garcia-Celma, “Nano-Emulsions,” *Current Opinion in Colloid & Interface Science* 10 (2005): 102–110, <https://doi.org/10.1016/j.cocis.2005.06.004>.
 52. R. K. Thareja and S. Shukla, “Synthesis and Characterization of Zinc Oxide Nanoparticles by Laser Ablation of Zinc in Liquid,” *Applied Surface Science* 253 (2007): 8889–8895, <https://doi.org/10.1016/j.apsusc.2007.04.088>.
 53. S. Polarz, A. Roy, M. Merz, et al., “Chemical Vapor Synthesis of Size-Selected Zinc Oxide Nanoparticles,” *Small* 1 (2005): 540–552, <https://doi.org/10.1002/sml.200400085>.
 54. V. Kumar and S. Kumar, “Synthesis and Characterization of ZnO Nanoparticles Using Combustion Method,” *AIP Conference Proceedings* 1393 (2011): 331–332, <https://doi.org/10.1063/1.3653744>.
 55. P. Rajiv, S. Rajeshwari, and R. Venkatesh, “Bio-Fabrication of Zinc Oxide Nanoparticles Using Leaf Extract of *Parthenium Hysterophorus* L. and Its Size-Dependent Antifungal Activity Against Plant Fungal Pathogens,” *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 112 (2013): 384–387, <https://doi.org/10.1016/j.saa.2013.04.072>.
 56. R. Raliya and J. C. Tarafdar, “Biosynthesis and Characterization of Zinc, Magnesium and Titanium Nanoparticles: An Eco-Friendly Approach,” *International Nano Letters* 4 (2014): 93, <https://doi.org/10.1007/s40089-014-0093-8>.
 57. M. Elaigwu, H. O. A. Oluma, C. U. Aguoru, and A. Onekutu, “Screening and Phytochemical Analysis of Some Plants Extracts Against Aflatoxin Producing Fungi in Sesame, Benue State, Nigeria,” *American Journal of Plant Sciences* 11 (2020): 344–353, <https://doi.org/10.4236/ajps.2020.113025>.
 58. H. Greathead, “Plants and Plant Extracts for Improving Animal Productivity,” *Proceedings of the Nutrition Society* 62 (2003): 279–290, <https://doi.org/10.1079/PNS2002197>.
 59. A. Ghosh, N. Chowdhury, and G. Chandra, “Plant Extracts as Potential Mosquito Larvicides,” *Indian Journal of Medical Research* 135 (2012): 581–598.
 60. S. Dixit and H. Ali, “Anticancer Activity of Medicinal Plant Extract-A Review,” *Journal of Chemistry and Chemical Sciences* 1 (2010): 79–85.
 61. F. Pohl and P. Kong Thoo Lin, “The Potential Use of Plant Natural Products and Plant Extracts With Antioxidant Properties for the Prevention/Treatment of Neurodegenerative Diseases: In Vitro,” *In Vivo and Clinical Trials, Molecules* 23 (2018): 3283, <https://doi.org/10.3390/molecules23123283>.
 62. N. Tripathi, V. Pavelyev, and S. S. Islam, “Synthesis of Carbon Nanotubes Using Green Plant Extract as Catalyst: Unconventional Concept and Its Realization,” *Applied Nanoscience* 7 (2017): 557–566, <https://doi.org/10.1007/s13204-017-0598-3>.
 63. S. H. Alrefaee, K. Y. Rhee, C. Verma, M. A. Quraishi, and E. E. Ebenso, “Challenges and Advantages of Using Plant Extract as Inhibitors in Modern Corrosion Inhibition Systems: Recent Advancements,” *Journal of Molecular Liquids* 321 (2021): 114666, <https://doi.org/10.1016/j.molliq.2020.114666>.
 64. B. Uzair, A. Liaqat, H. Iqbal, et al., “Green and Cost-Effective Synthesis of Metallic Nanoparticles by Algae: Safe Methods for Translational Medicine,” *Bioengineering* 7 (2020): 129, <https://doi.org/10.3390/bioengineering7040129>.
 65. V. K. Ahluwalia and M. Kidwai, *New Trends in Green Chemistry* (Springer Science & Business Media, 2012).
 66. P. D. Darbre, Chapter 5 - Plant-Based Ingredients in Personal Care products, in *Personal Care Products and Human Health*, ed. P.D. Darbre, (Academic Press, 2023), 97–112, <https://doi.org/10.1016/B978-0-323-99684-6.00012-4>.
 67. M. G. Rasul, “Conventional Extraction Methods Use in Medicinal Plants, Their Advantages and Disadvantages,” *International Journal of Basic Sciences and Applied Computing* 2 (2018): 10–14.
 68. B. A. Abbasi, J. Iqbal, J. A. Nasir, et al., “Environmentally Friendly Green Approach for the Fabrication of Silver Oxide Nanoparticles: Characterization and Diverse Biomedical Applications,” *Microscopy Res & Technique* 83 (2020): 1308–1320, <https://doi.org/10.1002/jemt.23522>.
 69. R. O. Abdulmaleek, G. I. Ndukwe, and P. A. Ekwumemgbo, “Green Route Synthesis and Characterization of Silver Oxide Nanoparticles Using Ocimum Gratissimum Leaf Extract,” *Journal of Materials and Environmental Science* 14 (2023): 1494–1503.
 70. C. Ashokraja, M. Sakar, and S. Balakumar, “A Perspective on the Hemolytic Activity of Chemical and Green-synthesized Silver and Silver Oxide Nanoparticles,” *Materials Research Express* 4 (2017): 105406, <https://doi.org/10.1088/2053-1591/aa90f2>.
 71. B. El-Ghmar, H. Farah, and A. Ech-Chahad, “A New Approach for the Green Biosynthesis of Silver Oxide Nanoparticles Ag_2O , Characterization and Catalytic Application,” *Bulletin of Chemical Reaction Engineering & Catalysis* 16 (2021): 651–660, <https://doi.org/10.9767/bcrec.16.3.11577.651-660>.
 72. S. Haq, K. A. Yasin, W. Rehman, et al., “Green Synthesis of Silver Oxide Nanostructures and Investigation of Their Synergistic Effect With Moxifloxacin against Selected Microorganisms,” *Journal of Inorganic and Organometallic Polymers* 31 (2021): 1134–1142, <https://doi.org/10.1007/s10904-020-01763-8>.
 73. R. Li, Z. Chen, N. Ren, Y. Wang, Y. Wang, and F. Yu, “Biosynthesis of Silver Oxide Nanoparticles and Their Photocatalytic and Antimicrobial Activity Evaluation for Wound Healing Applications in Nursing Care,” *Journal of Photochemistry and Photobiology B: Biology* 199 (2019): 111593, <https://doi.org/10.1016/j.jphotobiol.2019.111593>.
 74. G. Maheshwaran, A. Nivedhitha Bharathi, M. Malai Selvi, M. Krishna Kumar, R. Mohan Kumar, and S. Sudhahar, “Green Synthesis of Silver Oxide Nanoparticles Using Zephyranthes Rosea Flower Extract and Evaluation of Biological Activities,” *Journal of Environmental Chemical Engineering* 8 (2020): 104137, <https://doi.org/10.1016/j.jece.2020.104137>.
 75. G. Pradheesh, S. Suresh, J. Suresh, and V. Alexramani, “Antimicrobial and Anticancer Activity Studies on Green Synthesized Silver Oxide Nanoparticles From the Medicinal Plant *Cyathia Nilgiriensis* Holtttum,”

- International Journal of Pharmaceutical Investigation* 10 (2020): 146–150, <https://doi.org/10.5530/ijpi.2020.2.27>.
76. B. N. Rashmi, S. F. Harlapur, B. Avinash, et al., “Facile Green Synthesis of Silver Oxide Nanoparticles and Their Electrochemical, Photocatalytic and Biological Studies,” *Inorganic Chemistry Communications* 111 (2020): 107580, <https://doi.org/10.1016/j.inoche.2019.107580>.
 77. S. Ravichandran, V. Paluri, G. Kumar, K. Loganathan, and B. R. Kokati Venkata, “A Novel Approach for the Biosynthesis of Silver Oxide Nanoparticles Using Aqueous Leaf Extract of *Callistemon lanceolatus* (Myrtaceae) and Their Therapeutic Potential,” *Journal of Experimental Nanoscience* 11 (2016): 445–458, <https://doi.org/10.1080/17458080.2015.1077534>.
 78. A. Shah, S. Haq, W. Rehman, M. Waseem, S. Shoukat, and M. Rehman, “Photocatalytic and Antibacterial Activities of Paeonia Emodi Mediated Silver Oxide Nanoparticles,” *Materials Research Express* 6 (2019): 045045, <https://doi.org/10.1088/2053-1591/aaf4d2>.
 79. N. A. Şuţan, I. Fierăscu, C. Şuţan, et al., “In Vitro Mitodepressive Activity of Phytofabricated Silver Oxide Nanoparticles (Ag₂O-NPs) by Leaves Extract of *Helleborus Odorus* Waldst. & Kit. Ex Willd,” *Materials Letters* 286 (2021): 129194, <https://doi.org/10.1016/j.matlet.2020.129194>.
 80. M. S. S. Danish, L. L. Estrella-Pajulas, I. M. Alemaida, M. L. Grilli, A. Mikhaylov, and T. Senjyu, “Green Synthesis of Silver Oxide Nanoparticles for Photocatalytic Environmental Remediation and Biomedical Applications,” *Metals* 12 (2022): 769, <https://doi.org/10.3390/met12050769>.
 81. Y. Zidane, S. E. Laouini, A. Bouafia, et al., “Green Synthesis of Multifunctional MgO@AgO/Ag₂O Nanocomposite for Photocatalytic Degradation of Methylene Blue and Toluidine Blue,” *Frontiers in Chemistry* 10 (2022): 1083596, <https://doi.org/10.3389/fchem.2022.1083596>.
 82. N. K.h. Abdalameer, K. A. Khalaph, and E. M. Ali, “Ag/AgO Nanoparticles: Green Synthesis and Investigation of Their Bacterial Inhibition Effects,” *Materials Today: Proceedings* 45 (2021): 5788–5792, <https://doi.org/10.1016/j.matpr.2021.03.166>.
 83. A. A. Fayyadh and M. H. J. Alzubaidy, “Green-Synthesis of Ag₂O Nanoparticles for Antimicrobial Assays**,” *Journal of the Mechanical Behavior of Materials* 30 (2021): 228–236, <https://doi.org/10.1515/jmbm-2021-0024>.
 84. S. G. Daghighan, M. R. Farahpour, and S. Jafarirad, “Biological Fabrication and Electrostatic Attractions of New Layered Silver/Talc Nanocomposite Using *Lawsonia inermis* L. and Its Chitosan-Capped Inorganic/Organic Hybrid: Investigation on Acceleration of *Staphylococcus aureus* and *Pseudomonas aeruginosa* Infected Wound Healing,” *Materials Science and Engineering: C* 128 (2021): 112294, <https://doi.org/10.1016/j.msec.2021.112294>.
 85. M. Dorairajan, V. Srinivas, V. Raju, and G. Raghavan, “Temperature Dependent Electrical Properties of Green Synthesized Silver Nanoparticles-Polyaniline Composite,” *Advanced Materials Research* 938 (2014): 230–235, <https://doi.org/10.4028/www.scientific.net/AMR.938.230>.
 86. S. Mohanaparameswari, M. Balachandramohan, and P. Murugeswari, “Bio Synthesis and Characterization of Silver Nanoparticles by Leaf Extracts of *Moringa Oleifera* Leaf,” *Materials Today: Proceedings* 18 (2019): 1783–1791, <https://doi.org/10.1016/j.matpr.2019.05.277>.
 87. G. Rajagopal, “Green Synthesis and Characterization of Silver Oxide Nanoparticles Using Plant Extract,” *Scientific Reports* 6 (2019): 987–1004.
 88. M. Rabiei, A. Palevicius, A. Dashti, et al., “Measurement Modulus of Elasticity Related to the Atomic Density of Planes in Unit Cell of Crystal Lattices,” *Materials* 13 (2020): 4380, <https://doi.org/10.3390/ma13194380>.
 89. N. S. Flores-Lopez, J. A. Cervantes-Chávez, D. G. Téllez de Jesús, M. Cortez-Valadez, M. Estévez-González, and R. Esparza, “Bactericidal and Fungicidal Capacity of Ag₂O/Ag Nanoparticles Synthesized With Aloe Vera Extract,” *Journal of Environmental Science and Health, Part A* 56 (2021): 762–768, <https://doi.org/10.1080/10934529.2021.1925492>.
 90. N. J. Tamanna, M.d. Sahadat Hossain, N. Mohammed Bahadur, and S. Ahmed, “Green Synthesis of Ag₂O & Facile Synthesis of ZnO and Characterization Using FTIR, Bandgap Energy & XRD (Scherrer Equation, Williamson-Hall, Size-Train Plot, Monshi-Scherrer Model),” *Results in Chemistry* 7 (2024): 101313, <https://doi.org/10.1016/j.rechem.2024.101313>.
 91. R. Naaz, V. U. Siddiqui, S. U. Qadir, and W. A. Siddiqi, “Green Synthesis of Silver Nanoparticles Using Syngonium Podophyllum Leaf Extract and Its Antibacterial Activity,” *Materials Today: Proceedings* 46 (2021): 2352–2358, <https://doi.org/10.1016/j.matpr.2021.05.062>.
 92. S. Drummer, T. Madzimbamuto, and M. Chowdhury, “Green Synthesis of Transition-Metal Nanoparticles and Their Oxides: A Review,” *Materials* 14 (2021): 2700, <https://doi.org/10.3390/ma14112700>.
 93. U. P. Manik, A. Nande, S. Raut, and S. J. Dhoble, “Green Synthesis of Silver Nanoparticles Using Plant Leaf Extraction of *Artocarpus heterophyllus* and *Azadirachta indica*,” *Results in Materials* 6 (2020): 100086, <https://doi.org/10.1016/j.rinma.2020.100086>.
 94. Y. T. Prabhu, K. V. Rao, V. S. S. Kumar, and B. S. Kumari, “X-Ray Analysis by Williamson-Hall and Size-Strain Plot Methods of ZnO Nanoparticles With Fuel Variation,” *World Journal of Nano Science and Engineering* 4 (2014): 21–28, <https://doi.org/10.4236/wjnse.2014.41004>.
 95. H. R. Naika, K. Lingaraju, K. Manjunath, et al., “Green Synthesis of CuO Nanoparticles Using *Gloriosa Superba* L. extract and Their Antibacterial Activity,” *Journal of Taibah University for Science* 9 (2015): 7–12, <https://doi.org/10.1016/j.jtusci.2014.04.006>.
 96. V. U. Siddiqui, A. Ansari, R. Chauhan, and W. A. Siddiqi, “Green Synthesis of Copper Oxide (CuO) Nanoparticles by Punica Granatum Peel Extract,” *Materials Today: Proceedings* 36 (2021): 751–755, <https://doi.org/10.1016/j.matpr.2020.05.504>.
 97. M. Nasrollahzadeh, S. M. Sajadi, A. Rostami-Vartooni, and S. M. Hussin, “Green Synthesis of CuO Nanoparticles Using Aqueous Extract of *Thymus vulgaris* L. leaves and Their Catalytic Performance for N-Arylation of Indoles and Amines,” *Journal of Colloid and Interface Science* 466 (2016): 113–119, <https://doi.org/10.1016/j.jcis.2015.12.018>.
 98. S. Saif, A. Tahir, T. Asim, and Y. Chen, “Plant Mediated Green Synthesis of CuO Nanoparticles: Comparison of Toxicity of Engineered and Plant Mediated CuO Nanoparticles towards *Daphnia Magna*,” *Nanomaterials* 6 (2016): 205, <https://doi.org/10.3390/nano6110205>.
 99. H. Ahmad, K. Venugopal, A. H. Bhat, et al., “Enhanced Biosynthesis Synthesis of Copper Oxide Nanoparticles (CuO-NPs) for Their Antifungal Activity Toxicity Against Major Phyto-Pathogens of Apple Orchards,” *Pharmaceutical Research* 37 (2020): 246, <https://doi.org/10.1007/s11095-020-02966-x>.
 100. K. Velsankar, R. M. Aswin Kumar, R. Preethi, V. Muthulakshmi, and S. Sudhahar, “Green Synthesis of CuO Nanoparticles via *Allium sativum* Extract and Its Characterizations on Antimicrobial, Antioxidant, Antilavricidal Activities,” *Journal of Environmental Chemical Engineering* 8 (2020): 104123, <https://doi.org/10.1016/j.jece.2020.104123>.
 101. K. Gebremedhn, M. H. Kahsay, and M. Aklilu, “Green Synthesis of CuO Nanoparticles Using Leaf Extract of *Catha Edulis* and Its Antibacterial Activity,” *Journal of Pharmacy and Pharmacology* 7 (2019): 327–342, <https://doi.org/10.17265/2328-2150/2019.06.007>.
 102. G. Kalaiyan, K. M. Prabu, S. Suresh, and N. Suresh, “Green Synthesis of CuO Nanostructures With Bactericidal Activities Using *Simarouba glauca* Leaf Extract,” *Chemical Physics Letters* 761 (2020): 138062, <https://doi.org/10.1016/j.cplett.2020.138062>.
 103. K. R. Reddy, “Green Synthesis, Morphological and Optical Studies of CuO Nanoparticles,” *Journal of Molecular Structure* 1150 (2017): 553–557, <https://doi.org/10.1016/j.molstruc.2017.09.005>.
 104. B. Abderrhmane, M. Souhaila, C. Souheyla, et al., “Removal of Hydrocarbons and Heavy Metals From Petroleum Water by Modern Green Nanotechnology Methods,” *Scientific Reports* 13 (2023): 5637, <https://doi.org/10.1038/s41598-023-32938-1>.

105. S. Taghavi Fardood, A. Ramazani, P. A. Asiabi, and S. W. Joo, "A Novel Green Synthesis of Copper Oxide Nanoparticles Using a Henna Extract Powder," *Journal of Structural Chemistry* 59 (2018): 1737–1743, <https://doi.org/10.1134/S0022476618070302>.
106. S. Sharma and K. Kumar, "Aloe-vera Leaf Extract as a Green Agent for the Synthesis of CuO Nanoparticles Inactivating Bacterial Pathogens and Dye," *Journal of Dispersion Science and Technology* 42 (2021): 1950–1962, <https://doi.org/10.1080/01932691.2020.1791719>.
107. S. Gunalan, R. Sivaraj, and R. Venkatesh, "Aloe barbadensis Miller Mediated Green Synthesis of Mono-Disperse Copper Oxide Nanoparticles: Optical Properties," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 97 (2012): 1140–1144, <https://doi.org/10.1016/j.saa.2012.07.096>.
108. E. E. Elemike, D. C. Onwudiwe, N. Nundkumar, and M. Singh, "CuO and Au-CuO Nanoparticles Mediated by *Stigmaphyllon ovatum* Leaf Extract and Their Anticancer Potential," *Inorganic Chemistry Communications* 104 (2019): 93–97, <https://doi.org/10.1016/j.inoche.2019.03.039>.
109. R. Shashanka, "Investigation of Optical and Thermal Properties of CuO and ZnO Nanoparticles Prepared by Crocus Sativus (Saffron) Flower Extract," *Journal of the Iranian Chemical Society* 18 (2021): 415–427, <https://doi.org/10.1007/s13738-020-02037-3>.
110. K. Vishveshvar, M. V. Aravind Krishnan, K. Haribabu, and S. Vishnuprasad, "Green Synthesis of Copper Oxide Nanoparticles Using Ixiro Coccinea Plant Leaves and Its Characterization," *BioNanoScience* 8 (2018): 554–558, <https://doi.org/10.1007/s12668-018-0508-5>.
111. P. P. N. V. Kumar, U. Shameem, P. Kollu, R. L. Kalyani, and S. V. N. Pammi, "Green Synthesis of Copper Oxide Nanoparticles Using Aloe Vera Leaf Extract and Its Antibacterial Activity against Fish Bacterial Pathogens," *BioNanoScience* 5 (2015): 135–139, <https://doi.org/10.1007/s12668-015-0171-z>.
112. S. Anwaar, Q. Maqbool, N. Jabeen, et al., "The Effect of Green Synthesized CuO Nanoparticles on Callogenesis and Regeneration of *Oryza sativa* L.," *Frontiers in Plant Science* 7 (2016): 1330, <https://doi.org/10.3389/fpls.2016.01330>.
113. L.-B. Shi, P.-F. Tang, W. Zhang, Y.-P. Zhao, L.-C. Zhang, and H. Zhang, "Green Synthesis of CuO Nanoparticles Using *Cassia Auriculata* Leaf Extract and In Vitro Evaluation of Their Biocompatibility With Rheumatoid Arthritis Macrophages (RAW 264.7)," *Tropical Journal of Pharmaceutical Research* 16 (2017): 185, <https://doi.org/10.4314/tjpr.v16i1.25>.
114. H. Qamar, S. Rehman, D. K. Chauhan, A. K. Tiwari, V. Upmanyu, and G. Synthesis, "Characterization and Antimicrobial Activity of Copper Oxide Nanomaterial Derived From *Momordica charantia*," *International Journal of Nanomedicine* 15 (2020): 2541–2553, <https://doi.org/10.2147/IJN.S240232>.
115. P. C. N. Udayabhanu, M. A. Pavan Kumar, D. Suresh, et al., "Tinospora Cordifolia Mediated Facile Green Synthesis of Cupric Oxide Nanoparticles and Their Photocatalytic, Antioxidant and Antibacterial Properties," *Materials Science in Semiconductor Processing* 33 (2015): 81–88, <https://doi.org/10.1016/j.mssp.2015.01.034>.
116. R. Chowdhury, A. Khan, and M.d.H. Rashid, "Green Synthesis of CuO Nanoparticles Using *Lantana camara* Flower Extract and Their Potential Catalytic Activity towards the Aza-Michael Reaction," *RSC Advances* 10 (2020): 14374–14385, <https://doi.org/10.1039/D0RA01479F>.
117. G. Sharmila, R. Sakthi Pradeep, K. Sandiya, et al., "Biogenic Synthesis of CuO Nanoparticles Using Bauhinia Tomentosa Leaves Extract: Characterization and Its Antibacterial Application," *Journal of Molecular Structure* 1165 (2018): 288–292, <https://doi.org/10.1016/j.molstruc.2018.04.011>.
118. J. Sarkar, N. Chakraborty, A. Chatterjee, A. Bhattacharjee, D. Dasgupta, and K. Acharya, "Green Synthesized Copper Oxide Nanoparticles Ameliorate Defence and Antioxidant Enzymes in Lens Culinaris," *Nanomaterials* 10 (2020): 312, <https://doi.org/10.3390/nano10020312>.
119. S. Prakash, N. Elavarasan, A. Venkatesan, K. Subashini, M. Sowndharya, and V. Sujatha, "Green Synthesis of Copper Oxide Nanoparticles and Its Effective Applications in Biginelli Reaction, BTB Photodegradation and Antibacterial Activity," *Advanced Powder Technology* 29 (2018): 3315–3326, <https://doi.org/10.1016/j.apt.2018.09.009>.
120. K. Ganesan, V. K. Jothi, A. Natarajan, A. Rajaram, S. Ravichandran, and S. Ramalingam, "Green Synthesis of Copper Oxide Nanoparticles Decorated With Graphene Oxide for Anticancer Activity and Catalytic Applications," *Arabian Journal of Chemistry* 13 (2020): 6802–6814, <https://doi.org/10.1016/j.arabjc.2020.06.033>.
121. S. T. Karam and A. F. Abdulrahman, "Green Synthesis and Characterization of ZnO Nanoparticles by Using Thyme Plant Leaf Extract," *Photonics* 9 (2022): 594, <https://doi.org/10.3390/photonics9080594>.
122. S. Ahmed, S. A. C. Annu, and S. Ikram, "A Review on Biogenic Synthesis of ZnO Nanoparticles Using Plant Extracts and Microbes: A Prospect towards Green Chemistry," *Journal of Photochemistry and Photobiology B: Biology* 166 (2017): 272–284, <https://doi.org/10.1016/j.jphotobiol.2016.12.011>.
123. E. Darvishi, D. Kahrizi, and E. Arkan, "Comparison of Different Properties of Zinc Oxide Nanoparticles Synthesized by the Green (using *Juglans regia* L. Leaf Extract) and Chemical Methods," *Journal of Molecular Liquids* 286 (2019): 110831, <https://doi.org/10.1016/j.molliq.2019.04.108>.
124. H. Upadhyaya, S. Shome, R. Sarma, S. Tewari, M. K. Bhattacharya, and S. K. Panda, "Green Synthesis, Characterization and Antibacterial Activity of ZnO Nanoparticles," *American Journal of Plant Sciences* 09 (2018): 1279–1291, <https://doi.org/10.4236/ajps.2018.96094>.
125. S. Fakhari, M. Jamzad, and H. K. Fard, "Green Synthesis of Zinc Oxide Nanoparticles: A Comparison," *Green Chemistry Letters and Reviews* 12 (2019): 19–24, <https://doi.org/10.1080/17518253.2018.1547925>.
126. M. Ramesh, M. Anbuvarannan, and G. Viruthagiri, "Green Synthesis of ZnO Nanoparticles Using Solanum Nigrum Leaf Extract and Their Antibacterial Activity," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* 136 (2015): 864–870, <https://doi.org/10.1016/j.saa.2014.09.105>.
127. R. Rathnasamy, P. Thangasamy, R. Thangamuthu, S. Sampath, and V. Alagan, "Green Synthesis of ZnO Nanoparticles Using Carica Papaya Leaf Extracts for Photocatalytic and Photovoltaic Applications," *Journal of Materials Science: Materials in Electronics* 28 (2017): 10374–10381, <https://doi.org/10.1007/s10854-017-6807-8>.
128. V. S. Sivasankarapillai, N. Krishnamoorthy, G. E. Eldesoky, et al., "One-pot Green Synthesis of ZnO Nanoparticles Using Scoparia Dulcis Plant Extract for Antimicrobial and Antioxidant Activities," *Applied Nanoscience* 13 (2023): 6093–6103, <https://doi.org/10.1007/s13204-022-02610-7>.
129. C. A. Soto-Robles, P. A. Luque, C. M. Gómez-Gutiérrez, et al., "Study on the Effect of the Concentration of *Hibiscus sabdariffa* Extract on the Green Synthesis of ZnO Nanoparticles," *Results in Physics* 15 (2019): 102807, <https://doi.org/10.1016/j.rinp.2019.102807>.
130. W. Ahmad and D. Kalra, "Green Synthesis, Characterization and Anti Microbial Activities of ZnO Nanoparticles Using *Euphorbia hirta* Leaf Extract," *Journal of King Saud University—Science* 32 (2020): 2358–2364, <https://doi.org/10.1016/j.jksus.2020.03.014>.
131. U. Wijesinghe, G. Thiripuranathar, F. Menaa, and H. Almkhelifi, "Eco-Friendly Synthesis of Zinc Oxide Nanoparticles and Assessment of Their Activities as Efficient Antioxidant Agents," *Current Nanoscience* 19 (2023): 132–146, <https://doi.org/10.2174/1573413718666220513094848>.
132. U. Wijesinghe, G. Thiripuranathar, F. Menaa, H. Iqbal, A. Razzaq, and H. Almkhelifi, "Green Synthesis, Structural Characterization and Photocatalytic Applications of ZnO Nanoconjugates Using *Heliotropium indicum*," *Catalysts* 11 (2021): 831, <https://doi.org/10.3390/catal11070831>.
133. M. Ahmad, W. Rehman, M. M. Khan, et al., "Phytogenic Fabrication of ZnO and Gold Decorated ZnO Nanoparticles for Photocatalytic Degra-

- dation of Rhodamine B,” *Journal of Environmental Chemical Engineering* 9 (2021): 104725, <https://doi.org/10.1016/j.jece.2020.104725>.
134. U. Wijesinghe, G. Thiripuranathar, H. Iqbal, and F. Mena, “Biomimetic Synthesis, Characterization, and Evaluation of Fluorescence Resonance Energy Transfer, Photoluminescence, and Photocatalytic Activity of Zinc Oxide Nanoparticles,” *Sustainability* 13 (2021): 2004, <https://doi.org/10.3390/su13042004>.
 135. S. S. Ahmed, A. M. Alqahtani, T. Alqahtani, et al., “Characterizations of Zinc Oxide Nanoparticles From Aqueous Leaf Extract of *Tridax Procumbens* Linn. And Assessment of Their Anti-Hyperglycemic Activity in Streptozotocin-Induced Diabetic Rats,” *Materials* 15 (2022): 8202, <https://doi.org/10.3390/ma15228202>.
 136. B. Gherbi, S. E. Laouini, S. Meneceur, et al., “Effect of pH Value on the Bandgap Energy and Particles Size for Biosynthesis of ZnO Nanoparticles: Efficiency for Photocatalytic Adsorption of Methyl Orange,” *Sustainability* 14 (2022): 11300, <https://doi.org/10.3390/su141811300>.
 137. T. Tanweer, N. F. Rana, I. Saleem, et al., “Dental Composites With Magnesium Doped Zinc Oxide Nanoparticles Prevent Secondary Caries in the Alloxan-Induced Diabetic Model,” *International Journal of Molecular Sciences* 23 (2022): 15926, <https://doi.org/10.3390/ijms232415926>.
 138. T. Tanweer, N. F. Rana, M. J. Khan, et al., “Transition Metal Doped Zinc Oxide Nanoparticles Ameliorates Antibacterial Potential of Dental Resin Composite in a Closed System In-Vitro Biofilm Model,” in 2022 E-Health and Bioengineering Conference (EHB), (IEEE, 2022), 1–4, <https://doi.org/10.1109/EHB55594.2022.9991374>.
 139. J. P. Usliyanage, G. Perera, G. Thiripuranathar, and F. Mena, “Synthetic Strategies of Ag-Doped ZnO Nanocomposites: A Comprehensive Review,” *Biomass Conversion and Biorefinery* 15 (2023): 19–39, <https://doi.org/10.1007/s13399-023-05139-z>.
 140. A. Dar, R. Rehman, W. Zaheer, U. Shafique, and J. Anwar, “Synthesis and Characterization of ZnO-Nanocomposites by Utilizing Aloe Vera Leaf Gel and Extract of *Terminalia arjuna* Nuts and Exploring Their Antibacterial Potency,” *Journal of Chemistry* 2021 (2021): 1–7, <https://doi.org/10.1155/2021/9448894>.
 141. G. Sangeetha, S. Rajeshwari, and R. Venkatesh, “Green Synthesis of Zinc Oxide Nanoparticles by *Aloe barbadensis* Miller Leaf Extract: Structure and Optical Properties,” *Materials Research Bulletin* 46 (2011): 2560–2566, <https://doi.org/10.1016/j.materresbull.2011.07.046>.
 142. L. M. Jose, R. S. A. Raj, D. Sajan, and A. Aravind, “Adsorption and Photocatalytic Activity of Biosynthesised ZnO Nanoparticles Using Aloe Vera Leaf Extract,” *Nano Express* 2 (2021): 010039, <https://doi.org/10.1088/2632-959X/abec6c>.
 143. N. I. Rasli, H. Basri, and Z. Harun, “Zinc Oxide From Aloe Vera Extract: Two-level Factorial Screening of Biosynthesis Parameters,” *Heliyon* 6 (2020): e03156, <https://doi.org/10.1016/j.heliyon.2020.e03156>.
 144. S. Vijayakumar, P. Arulmozhi, N. Kumar, B. Sakthivel, S. P. Kumar, and P. K. Praseetha, “*Acalypha fruticosa* L. leaf Extract Mediated Synthesis of ZnO Nanoparticles: Characterization and Antimicrobial Activities,” *Materials Today: Proceedings* 23 (2020): 73–80, <https://doi.org/10.1016/j.matpr.2019.06.660>.
 145. M. F. Sohail, M. Rehman, S. Z. Hussain, et al., “Green Synthesis of Zinc Oxide Nanoparticles by Neem Extract as Multi-Facet Therapeutic Agents,” *Journal of Drug Delivery Science and Technology* 59 (2020): 101911, <https://doi.org/10.1016/j.jddst.2020.101911>.
 146. K. Elumalai and S. Velmurugan, “Green Synthesis, Characterization and Antimicrobial Activities of Zinc Oxide Nanoparticles From the Leaf Extract of *Azadirachta indica* (L.),” *Applied Surface Science* 345 (2015): 329–336, <https://doi.org/10.1016/j.apsusc.2015.03.176>.
 147. S. Ramesh, Z. Z. Loo, C. Y. Tan, et al., “Characterization of Biogenic Hydroxyapatite Derived From Animal Bones for Biomedical Applications,” *Ceramics International* 44 (2018): 10525–10530, <https://doi.org/10.1016/j.ceramint.2018.03.072>.
 148. V. V. Gawade, N. L. Gavade, H. M. Shinde, S. B. Babar, A. N. Kadam, and K. M. Garadkar, “Green Synthesis of ZnO Nanoparticles by Using *Calotropis procera* Leaves for the Photodegradation of Methyl Orange,” *Journal of Materials Science: Materials in Electronics* 28 (2017): 14033–14039, <https://doi.org/10.1007/s10854-017-7254-2>.
 149. T. S. Aldeen, H. E. Ahmed Mohamed, and M. Maaza, “ZnO Nanoparticles Prepared via a Green Synthesis Approach: Physical Properties, Photocatalytic and Antibacterial Activity,” *Journal of Physics and Chemistry of Solids* 160 (2022): 110313, <https://doi.org/10.1016/j.jpcs.2021.110313>.
 150. H. Sadiq, F. Sher, S. Sehar, et al., “Green Synthesis of ZnO Nanoparticles From *Syzygium cumini* Leaves Extract With Robust Photocatalysis Applications,” *Journal of Molecular Liquids* 335 (2021): 116567, <https://doi.org/10.1016/j.molliq.2021.116567>.
 151. D. Suresh, P. C. Nethravathi, H. R. Udayabhana, H. Nagabhushana, and S. C. Sharma, “Green Synthesis of Multifunctional Zinc Oxide (ZnO) Nanoparticles Using *Cassia fistula* Plant Extract and Their Photodegradative, Antioxidant and Antibacterial Activities,” *Materials Science in Semiconductor Processing* 31 (2015): 446–454, <https://doi.org/10.1016/j.mssp.2014.12.023>.
 152. S. O. Ogunyemi, Y. Abdallah, M. Zhang, et al., “Green Synthesis of Zinc Oxide Nanoparticles Using Different Plant Extracts and Their Antibacterial Activity Against *Xanthomonas oryzae* P. oryzae, Artificial Cells,” *Nanomedicine, and Biotechnology* 47 (2019): 341–352, <https://doi.org/10.1080/21691401.2018.1557671>.
 153. R. Ali, Z. J. Shanan, G. M. Saleh, and Q. Abass, “Green Synthesis and the Study of Some Physical Properties of MgO Nanoparticles and Their Antibacterial Activity,” *Iraqi Journal of Science* 61, no. 2 (2020): 266–276, <https://doi.org/10.24996/ij.s.2020.61.2.9>.
 154. A. Fatiqin, H. Amrulloh, and W. Simanjuntak, “Green Synthesis of MgO Nanoparticles Using *Moringa oleifera* Leaf Aqueous Extract for Antibacterial Activity,” *Bulletin of the Chemical Society of Ethiopia* 35 (2021): 161–170, <https://doi.org/10.4314/bcse.v35i1.14>.
 155. Y. S. Hii, J. Jeevanandam, and Y. S. Chan, “Plant Mediated Green Synthesis and Nanoencapsulation of MgO Nanoparticle From *Calotropis gigantea*: Characterisation and Kinetic Release Studies,” *Inorganic and Nano-Metal Chemistry* 48 (2018): 620–631, <https://doi.org/10.1080/24701556.2019.1569053>.
 156. S. K. Moorthy, C. h. Ashok, K. V. Rao, and C. Viswanathan, “Synthesis and Characterization of MgO Nanoparticles by Neem Leaves Through Green Method,” *Materials Today: Proceedings* 2 (2015): 4360–4368, <https://doi.org/10.1016/j.matpr.2015.10.027>.
 157. S. Saman, A. Balouch, F. N. Talpur, A. A. Memon, B. M. Mousavi, and F. Verpoort, “Green Synthesis of MgO Nanocatalyst by Using *ZIZIPHUS MAURITIANA* Leaves and Seeds for Biodiesel Production,” *Applied Organometallic Chemistry* 35 (2021): e6199, <https://doi.org/10.1002/aoc.6199>.
 158. B. K. Sharma, B. R. Mehta, V. P. Chaudhari, E. V. Shah, S. Mondal Roy, and D. R. Roy, “Green Synthesis of Dense Rock MgO Nanoparticles Using Carica Papaya Leaf Extract and Its Shape Dependent Antimicrobial Activity: Joint Experimental and DFT Investigation,” *Journal of Cluster Science* 33 (2022): 1667–1675, <https://doi.org/10.1007/s10876-021-02090-9>.
 159. A. Akshaykranth, N. Jayarambabu, V. R. Tumu, and R. K. Rajaboina, “Comparative Study on Antibacterial Activity of MgO Nanoparticles Synthesized From *Lawsonia inermis* Leaves Extract and Chemical Methods,” *Journal of Inorganic and Organometallic Polymers* 31 (2021): 2393–2400, <https://doi.org/10.1007/s10904-021-01915-4>.
 160. J. Jeevanandam, Y. S. Chan, and Y. H. Ku, “Aqueous Eucalyptus Globulus Leaf Extract-Mediated Biosynthesis of MgO Nanorods,” *Applied Biological Chemistry* 61 (2018): 197–208, <https://doi.org/10.1007/s13765-018-0347-7>.
 161. A. Khan, D. Shabir, P. Ahmad, M. U. Khandaker, M. R. I. Faruque, and I. U. Din, “Biosynthesis and Antibacterial Activity of MgO-NPs Produced From *Camellia-sinensis* Leaves Extract,” *Materials Research Express* 8 (2021): 015402, <https://doi.org/10.1088/2053-1591/abd421>.

162. L. Umaralikhan and M. Jamal Mohamed Jaffar, "Green Synthesis of MgO Nanoparticles and Its Antibacterial Activity," *Iranian Journal of Science and Technology Transaction A: Science* 42 (2018): 477–485, <https://doi.org/10.1007/s40995-016-0041-8>.
163. S. Stankic, M. Cottura, D. Demaille, C. Noguera, and J. Jupille, "Nucleation and Growth Concepts Applied to the Formation of a Stoichiometric Compound in a Gas Phase: The Case of MgO Smoke," *Journal of Crystal Growth* 329 (2011): 52–56, <https://doi.org/10.1016/j.jcrysgro.2011.05.029>.
164. Annu, A. Ali, and S. Ahmed, "Green Synthesis of Metal, Metal Oxide Nanoparticles, and Their Various Applications," in *Handbook of Ecomaterials*, ed. L. Martinez, O. Kharissova, and B. Kharisov (Springer, 2019), 2281–2325, https://doi.org/10.1007/978-3-319-68255-6_115.
165. M. I. Khan, M. N. Akhtar, N. Ashraf, et al., "Green Synthesis of Magnesium Oxide Nanoparticles Using Dalbergia Sissoo Extract for Photocatalytic Activity and Antibacterial Efficacy," *Applied Nanoscience* 10 (2020): 2351–2364, <https://doi.org/10.1007/s13204-020-01414-x>.
166. J. Suresh, G. Pradheesh, V. Alexramani, M. Sundarajan, and S. I. Hong, "Green Synthesis and Characterization of Hexagonal Shaped MgO Nanoparticles Using Insulin Plant (*Costus pictus* D. Don) Leave Extract and Its Antimicrobial as Well as Anticancer Activity," *Advanced Powder Technology* 29 (2018): 1685–1694, <https://doi.org/10.1016/j.appt.2018.04.003>.
167. Y. Zidane, S. E. Laouini, A. Bouafia, et al., "Green Synthesis of Multifunctional MgO@AgO/Ag₂O Nanocomposite for Photocatalytic Degradation of Methylene Blue and Toluidine Blue," *Frontiers in Chemistry* 10 (2022): 1083596, <https://doi.org/10.3389/fchem.2022.1083596>.
168. A. Venkatachalam, J. P. Jesuraj, and K. Sivaperuman, "Moringa Oleifera Leaf Extract-Mediated Green Synthesis of Nanostructured Alkaline Earth Oxide (MgO) and Its Physicochemical Properties," *Journal of Chemistry* 2021 (2021): 1–22, <https://doi.org/10.1155/2021/4301504>.
169. E. R. Essien, V. N. Atasi, A. O. Okefor, and D. O. Nwude, "Biogenic Synthesis of Magnesium Oxide Nanoparticles Using *Manihot esculenta* (Crantz) Leaf Extract," *International Nano Letters* 10 (2020): 43–48, <https://doi.org/10.1007/s40089-019-00290-w>.
170. P. Praveen Kumar, M. Laxmi Deepak Bhatlu, K. Sukanya, S. Karthikeyan, and N. Jayan, "Synthesis of Magnesium Oxide Nanoparticle by Eco Friendly Method (Green Synthesis) – A Review," *Materials Today: Proceedings* 37 (2021): 3028–3030, <https://doi.org/10.1016/j.matpr.2020.08.726>.
171. A. Nadeem, J. S. A. Sumbal, M. Latif, et al., "Green Synthesis and Characterization of Fe, Cu and Mg Oxide Nanoparticles Using *Clematis orientalis* Leaf Extract: Salt Concentration Modulates Physiological and Biological Properties," *Materials Chemistry and Physics* 271 (2021): 124900, <https://doi.org/10.1016/j.matchemphys.2021.124900>.
172. J. Osuntokun, D. C. Onwudiwe, and E. E. Ebenso, "Aqueous Extract of Broccoli Mediated Synthesis of CaO Nanoparticles and Its Application in the Photocatalytic Degradation of Bromocresol Green," *IET Nanobiotechnology* 12 (2018): 888–894, <https://doi.org/10.1049/iet-nbt.2017.0277>.
173. B. Ramola and N. C. Joshi, "Green Synthesis, Characterisations and Antimicrobial Activities of CaO Nanoparticles," *Oriental Journal of Chemistry* 35 (2019): 1154–1157, <https://doi.org/10.13005/ojc/350333>.
174. J. Yoonus, R. Resmi, and B. Beena, "Greener Nanoscience: Piper betel Leaf Extract Mediated Synthesis of CaO Nanoparticles and Evaluation of Its Antibacterial and Anticancer Activity," *Materials Today: Proceedings* 41 (2021): 535–540, <https://doi.org/10.1016/j.matpr.2020.05.246>.
175. U. Ijaz, I. A. Bhatti, S. Mirza, and A. Ashar, "Characterization and Evaluation of Antibacterial Activity of Plant Mediated Calcium Oxide (CaO) Nanoparticles by Employing *Mentha pipertia* Extract," *Materials Research Express* 4 (2017): 105402, <https://doi.org/10.1088/2053-1591/aa8603>.
176. V. Jadhav, A. Bhagare, S. Wahab, et al., "Green Synthesized Calcium Oxide Nanoparticles (CaO NPs) Using Leaves Aqueous Extract of *Moringa oleifera* and Evaluation of Their Antibacterial Activities," *Journal of Nanomaterials* 2022 (2022): 1–7, <https://doi.org/10.1155/2022/9047507>.
177. A. Anantharaman, "Green Synthesis of Calcium Oxide Nanoparticles and Its Applications," *International Journal of Engineering Research and Application* 6 (2016): 27–31.
178. M. R. Abukhadra, M. G. Basyouny, A. M. El-Sherbeen, M. A. El-Meligy, and M. Luqman, "Sonocogreen Decoration of Clinoptilolite by CaO Nanorods as Ecofriendly Catalysts in the Transesterification of Castor Oil Into Biodiesel; Response Surface Studies," *ACS Omega* 6 (2021): 1556–1567, <https://doi.org/10.1021/acsomega.0c05371>.
179. D. Jagadeesh, K. Prashantha, and R. Shabadi, "Star-Shaped Sucrose-Capped CaO Nanoparticles From *Azadirachta indica*: A Novel Green Synthesis," *Inorganic and Nano-Metal Chemistry* 47 (2017): 708–712, <https://doi.org/10.1080/15533174.2016.1212231>.
180. G. Marquis, B. Ramasamy, S. Banwarilal, and A. P. Munusamy, "Evaluation of Antibacterial Activity of Plant Mediated CaO Nanoparticles Using C Issus Quadrangularis Extract," *Journal of Photochemistry and Photobiology B: Biology* 155 (2016): 28–33, <https://doi.org/10.1016/j.jphotobiol.2015.12.013>.
181. S. Pervez, S. Hassan, S. Mughal, A. Pando, A. Butt, and N. Shabbir, "Structural, Morphological and Biotoxicity Studies of Biosynthesized CaO Nanoparticles via Cuminum Cyminum," *Advances in Materials* 11 (2022): 37–49, <https://doi.org/10.11648/j.am.20221102.12>.
182. B. Yazıcılar, F. Böke, A. Alaylı, H. Nadaroglu, S. Gedikli, and I. Bezirganoglu, "In Vitro Effects of CaO Nanoparticles on Triticale Callus Exposed to Short and Long-Term Salt Stress," *Plant Cell Reports* 40 (2021): 29–42, <https://doi.org/10.1007/s00299-020-02613-0>.
183. A. Mobeen Amanulla and R. Sundaram, "Green Synthesis of TiO₂ Nanoparticles Using Orange Peel Extract for Antibacterial, Cytotoxicity and Humidity Sensor Applications," *Materials Today: Proceedings* 8 (2019): 323–331, <https://doi.org/10.1016/j.matpr.2019.02.118>.
184. S. Subhapriya and P. Gomathipriya, "Green Synthesis of Titanium Dioxide (TiO₂) Nanoparticles by Trigonella Foenum-Graecum Extract and Its Antimicrobial Properties," *Microbial Pathogenesis* 116 (2018): 215–220, <https://doi.org/10.1016/j.micpath.2018.01.027>.
185. B. K. Thakur, A. Kumar, and D. Kumar, "Green Synthesis of Titanium Dioxide Nanoparticles Using *Azadirachta indica* Leaf Extract and Evaluation of Their Antibacterial Activity," *South African Journal of Botany* 124 (2019): 223–227, <https://doi.org/10.1016/j.sajb.2019.05.024>.
186. T. Santhoshkumar, A. A. Rahuman, C. Jayaseelan, et al., "Green Synthesis of Titanium Dioxide Nanoparticles Using *Psidium guajava* Extract and Its Antibacterial and Antioxidant Properties," *Asian Pacific Journal of Tropical Medicine* 7 (2014): 968–976, [https://doi.org/10.1016/S1995-7645\(14\)60171-1](https://doi.org/10.1016/S1995-7645(14)60171-1).
187. S. P. Goutam, G. Saxena, V. Singh, A. K. Yadav, R. N. Bharagava, and K. B. Thapa, "Green Synthesis of TiO₂ Nanoparticles Using Leaf Extract of *Jatropha curcas* L. for Photocatalytic Degradation of Tannery Wastewater," *Chemical Engineering Journal* 336 (2018): 386–396, <https://doi.org/10.1016/j.cej.2017.12.029>.
188. M. Aravind, M. Amalanathan, and M. S. M. Mary, "Synthesis of TiO₂ Nanoparticles by Chemical and Green Synthesis Methods and Their Multifaceted Properties," *SN Applied Science* 3 (2021): 409, <https://doi.org/10.1007/s42452-021-04281-5>.
189. A. Ansari, V. U. Siddiqui, W. U. Rehman, et al., "Green Synthesis of TiO₂ Nanoparticles Using Acorus Calamus Leaf Extract and Evaluating Its Photocatalytic and in Vitro Antimicrobial Activity," *Catalysts* 12 (2022): 181, <https://doi.org/10.3390/catal12020181>.
190. K. Elattar, F. Alotibi, M. El-Hersh, et al., "Multifaceted Chemical and Bioactive Features of Ag@TiO₂ and Ag@SeO₂ Core/Shell Nanoparticles Biosynthesized Using *Beta vulgaris* L. Extract," *Heliyon* 10 (2024): e28359, <https://doi.org/10.1016/j.heliyon.2024.e28359>.
191. A. A. Fayyadh and M. H. Jaduaa Alzubaidy, "Green-Synthesis of Ag₂O Nanoparticles for Antimicrobial Assays **," *Journal of the Mechan-*

cal Behavior of Materials 30 (2021): 228–236, <https://doi.org/10.1515/jmbm-2021-0024>.

192. T. Pushpamalini, M. Keerthana, R. Sangavi, A. Nagaraj, and P. Kamaraj, “Comparative Analysis of Green Synthesis of TiO₂ Nanoparticles Using Four Different Leaf Extract,” *Materials Today: Proceedings* 40 (2021): S180–S184, <https://doi.org/10.1016/j.matpr.2020.08.438>.

193. U. H. Bhat, M. Uddin, A. S. Chishti, et al., “Enhancing Growth, Vitality, and Aromatic Richness: Unveiling the Dual Magic of Silicon Dioxide and Titanium Dioxide Nanoparticles in *Ocimum tenuiflorum*,” *Frontiers in Plant Science* 15 (2024): 1335965, <https://doi.org/10.3389/fpls.2024.1335965>.

194. J. Roy, “The Synthesis and Applications of TiO₂ Nanoparticles Derived From Phytochemical Sources,” *Journal of Industrial and Engineering Chemistry* 106 (2022): 1–19, <https://doi.org/10.1016/j.jiec.2021.10.024>.

195. H. Kaur, S. Kaur, J. Singh, M. Rawat, and S. Kumar, “Expanding Horizon: Green Synthesis of TiO₂ Nanoparticles Using Carica Papaya Leaves for Photocatalysis Application,” *Materials Research Express* 6 (2019): 095034, <https://doi.org/10.1088/2053-1591/ab2ec5>.

196. A. Panneerselvam, J. Velayutham, and S. Ramasamy, “Green Synthesis of TiO₂ Nanoparticles Prepared From *Phyllanthus niruri* Leaf Extract for Dye Adsorption and Their Isotherm and Kinetic Studies,” *IET Nanobiotechnology* 15 (2021): 164–172, <https://doi.org/10.1049/nbt2.12033>.

197. F. D. Koca and F. Duman, “Genotoxic and Cytotoxic Activity of Green Synthesized TiO₂ Nanoparticles,” *Applied Nanoscience* 9 (2019): 815–823, <https://doi.org/10.1007/s13204-018-0712-1>.

198. M. Hanafy, “Green Synthesis and Characterization of TiO₂ Nanoparticles Using Aloe Vera Extract at Different pH Value,” *Scientific Journal of King Faisal University* 21, no. 1 (2020): 1441, <https://doi.org/10.37575/b/sci/2020>.

199. M. Hudlikar, S. Joglekar, M. Dhaygude, and K. Kodam, “Green Synthesis of TiO₂ Nanoparticles by Using Aqueous Extract of *Jatropha curcas* L. latex,” *Materials Letters* 75 (2012): 196–199, <https://doi.org/10.1016/j.matlet.2012.02.018>.

200. N. S. Alsaiari, F. M. Alzahrani, A. Amari, et al., “Plant and Microbial Approaches as Green Methods for the Synthesis of Nanomaterials: Synthesis, Applications, and Future Perspectives,” *Molecules* 28 (2023): 463, <https://doi.org/10.3390/molecules28010463>.

201. M. A. B. Turkia and T. A. Salman, “A Review on the Synthesis of Nanomaterials: Comparing Traditional and Biological Green Methods,” *Journal of Chemical Reviews* 6 (2024): 458–481, <https://doi.org/10.48309/jcr.2024.468135.1350>.

202. M. M. Ahmad, H. M. Kotb, S. Mushtaq, M. Waheed-Ur-Rehman, C. M. Maghanga, and M. W. Alam, “Green Synthesis of Mn + Cu Bimetallic Nanoparticles Using Vinca Rosea Extract and Their Antioxidant, Antibacterial, and Catalytic Activities,” *Crystals* 12 (2022): 72, <https://doi.org/10.3390/cryst12010072>.

203. R. A. Banjara, A. Kumar, R. K. Aneshwari, M. L. Satnami, and S. K. Sinha, “A Comparative Analysis of Chemical vs Green Synthesis of Nanoparticles and Their Various Applications,” *Environmental Nanotechnology, Monitoring & Management* 22 (2024): 100988, <https://doi.org/10.1016/j.enmm.2024.100988>.

204. M. Noor, K. Bangash, M. Abbas, et al., “Potential and Challenges in Green Synthesis of Nanoparticles: A Review, Xi’an Shiyou Daxue Xuebao (Ziran Kexue Ban),” *Journal of Xi’an Shiyou University* 19 (2023): 1155–1165.