Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

An Eco-friendly Approach - Synthesis and Characterization of CuO nanoparticles

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ABSTRACT

Nanoparticles hold excellent and attractive properties due to their small sizes, large surface area, free hanging bonds and superior reactivity. Nanoparticles (NPs) are a part of nanomaterial that is defined as a single particle 1–100 nm in diameter. From last few years, nanoparticles have been a conventional material for the development of new cutting-edge applications in communications, energy storage, sensing, data storage, optics, transmission, environmental protection, cosmetics, biology, and medicine due to their essential optical, electrical, and magnetic properties. Synthesis of nanoparticles can be performed using a number of routinely used chemical and physical methods. Chemical synthesis methods for NPs include emulsion solvent extraction method, double emulsion, and an evaporation method, salting out method, emulsion diffusion method, and solvent displacement/precipitation method. But, industrial-scale production of NPs has familiarized a new kind of pollution into the environment. Thus, there is a need for "green synthesis" that includes a clean, safe, eco-friendly and environmentally nontoxic method of nanoparticle synthesis. Various reports emphasize that plant-based nanoparticles had the valuable impact on agriculture, pharmaceuticals, drug delivery and production of other commercial goods. Use of plant extracts as natural reducing, capping and stabilizing agents have been attained considerable progress. Green synthesis method avoids inert gases, high pressure, laser radiation, high temperature, toxic chemicals etc. as compared to the conventional method like sol-gel technique method, laser ablation method, inert gas condensation method, chemical reduction method etc. The structures, morphology, optical properties, surface area and thermal behavior of these fabricated nanoparticles were characterized by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Ultraviolet-visible spectroscopy (UV-vis), Photoluminescence (PL)/fluorescence spectroscopy and Fourier transform infrared spectroscopy (FTIR) analysis. This review is a comprehensive study of the synthesis, structure and physiochemical characterization methods used for synthesis of CuO NPs via green approach.

KEY WORDS: Green synthesis of nanoparticles, FT-IR, XRD, SEM, CuO NPs.

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INTRODUCTION

"Nanotechnology is the application of science to control matter at the molecular level"[1].Nanotechnology deals with the science and engineering of creating functional materials and devices between 0.1 to 100 nanometer scale in any dimension and is the most commercially viable technology of the 21st century. Tremendous growth in nanotechnology has opened up novel fundamental and applied frontiers in materials science and engineering, such as Nano biotechnology[2], bio nanotechnology[3], quantum dots[4], surface-enhanced Raman scattering (SERS) [5], and applied microbiology. Nanoparticles have been intensively studied over the last decade due to their characteristics: physical, chemical, electronic, electrical, mechanical, magnetic, thermal, dielectric, optical and biological properties[6,7]. Non-Toxic property of nanoparticles has been utilized for cancer cell treatment.[8-10]. Metal oxide nanoparticles are of much interest because of their unique optical, electronic and magnetic properties. The transition metal oxide are acting as semiconductors and can be utilized as magnetic storage media, solar energy transformation, electronics, gas sensors and catalyst [11-15]. Numerous physical and chemical methods have been broadly used to produce Nano crystalline copper oxide such as micro emulsion method[16], arc-submerged nanoparticle synthesis system[17], flame-based aerosol methods[18], nonchemical[19], hydrothermal[20] and solid-state techniques[21]. When hazardous chemicals are used on the surface of nanoparticles and non-polar solvents in the synthesis procedure it decreases the chances of use of Nano materials in clinical field. Hence eco-friendly methods for synthesis are raise as it gives biocompatible and non-toxic nanoparticles. The most prominent eco-friendly method of recent interest is green approach. These approaches focus on utilization of environment-friendly, cost-effective and biocompatible reducing agents for synthesis of nanoparticles. Numerous biomaterials used for synthesis of NPs, but plant are very less toxic amongst them and nanoparticles produced by plants are more stable, are of various sizes and shapes[22]. The use of harsh chemicals such as hydrazine hydrate, sodium borohydride, dimethylformamide, ethylene glycol, and so on producing very toxic effects. To overcome this problem, biosynthetic and environment friendly methods are employed for synthesis of NPs. Many of these reducing agents have been associated with environmental toxicity or biological hazards. The synthesis of metal nanoparticles using inactivated plant tissue, plant extracts, exudates, and other parts of living plants is a modern alternative for their production[23]Cu, Cu_2O and CuO NPs.Copper nanoparticles caneasily oxidize to form copper oxide. If the application requires the copper nanoparticles to be protected from oxidation, the copper NPs are usually encapsulated in organic or inorganic material such as carbon and silica [24-27]. Review of literature revealed that synthesis of CuONPs using microorganisms and plant extract has been unexplored; there are only a very few reports on the use of yeast, fungi, bacteria or plant extract for synthesizing CONPs[28-30]. Different analytical techniques were used including UV–visible spectroscopy (UV–vis), Fourier transform infrared spectroscopy (FTIR), transmission electron microscopy (TEM) and X-ray diffraction analysis (XRD) for characterization of CONPs. Furthermore, the bacterial effect of CONPs was also analyzed by disc diffusion method. The current review highlights the information about different methodology and plant extract used for synthesis of copper oxide nanoparticles and further this information can be employed for understanding the properties and behavior of CuO nanoparticles in different applications.

MATERIALS AND METHODS

1. *Green synthesis of copper oxide nanoparticles using caricapapaya.*

Sankar et al., worked on synthesis of Copper oxide nanoparticles using cupric sulphate. Phytochemical present in the plant leaves act as reducing agent and able to reduce copper ions. Nanoparticles has been prepared via green approach. Further the confirmation of copper oxide nanoparticles has been done through XRD and size and shape confirmation via SEM. Synthesized nanoparticles were rod shape and size distribution was between 100-150nm. Further the application of nanoparticles in the field of dye degradation was observed.[31].

2. *Synthesis Copper Oxide Nanoparticles using Malvasylvestris Leaf Extract.*

Awwad*et al.*, used leaves of *Malvasylvestris* were collected in and around the campus of Royal Scientific Society, El Hassan Science City, Amman, Jordan. They synthesized copper oxide nanoparticles from *Malvasylvestris*and plant extract was treated with copper chloride dehydrate. Further XRD and SEM results clarify the confirmation of copper oxide nanoparticles. CuO NPs were further used as antimicrobial agent [32].

3. *Green synthesis of copper oxide nanoparticles using Gum karaya.*

M.Cernik*et al.*, reported the antimicrobial effect of copper oxide nanoparticles using *Gum karaya*. Plant leaves act as reducing agent and phytochemicals present plant reduce copper hydroxide to nano crystalline copper oxide nanoparticles. Antimicrobial activity checked with different gram positive and negative bacterial strains and study shows that nanoparticles have good antimicrobial property[33].

4. *Green synthesis of copper oxide nanoparticles using Tabernaemontana divaricate leaf extract.*

M. Nasrollahzadeh reported the synthesis of palladium copper oxide nanoparticles from leaves of *Tabernaemontana*. Polyphenols present in the plant can reduce the copper sulphate to copper oxide nanoparticles. The synthesized nanoparticles were further used as catalyst to 4-Nitrophenol[34].

5. *Green synthesis of CuOusing brown alga extract Bifurcaria bifurcate.*

Y. Abbound*et al.*, reported the antimicrobial activity of copper oxide nanoparticles synthesized from brown algae. Phytochemical of brown algae reduce Copper (II) sulphate to copper oxide nanoparticles.Nanoparticles of size range 5 nm to 50nm shows effective antimicrobial activity.[35].

STRUCTURE AND PHYSICO-CHEMICAL CHARACTERIZATION

Table No. 1: "Characterization of Nanoparticles."

Sr. No.	Author Name	Year of Publication	Type Of Nanoparticle	Type Of Characterization	Observation	Ref. no.
1.	Amrut. S. Lanje *et. al*	2010	CuO NP	SEM	Rectangular	36
				TEM	Size- 5-6 nm	
				XRD	Crystalline size 8 nm	
2.	Y. Abbounand *et. al*	2013	CuO NP using *Bifurcariybifurcate*	TEM	Size- 5-45 nm. Average size-20.66. Spherical and small percentage of elongated shaped particle.	35
				FT-IR	Peaks at 3413, 1730, 1625, 1103, 1033, 3000 and 1400 cm^{-1}.	
				XRD	2ϴ values 29.4º, 36.8º, 42.1º, 61.9º, and 77.6º.	
3.	ThekkaePadil and Cernic	2013	CuO NP using *Gum karaya*	SEM	Small needle like structure	33
				TEM	Size- 2-10 nm	
				FT-IR	Peaks at 3150, 3025, 1740, 1600, 1400, 1250, 1030, 525, 580, 675 cm^{-1}.	
				XRD	2ϴ values 32.47º, 35.49º, 38.68º, 48.65º, 53.36º, 58.25º, and 61.45º.	
4.	RenuSanker *et. al*	2014	CuO NP using *Carika papaya*	FT-IR	Peaks at 3444.4, 2926.79, 2858.10, 2363.93, 1880.01, 1636.69, 1391.64, 1087.31, 780.57, 691.12, 473.25 cm^{-1}	31
				XRD	2ϴ values 32.816º, 38.842º, 61.403º and	

					71.189º.	
5.	Awwad, A.M. *et. al*	2015	CuO NP using *Malvasylvestris*	SEM	Spherical, size- 5-30 nm.	32
				FT-IR	Peaks at 3444, 3398, 2924, 2846, 1734, 1604, 513 cm^{-1}.	
				XRD	2θ values of 32.49º, 35.49º, 38.96º, 48.73º, 53.45º, 58.34º, 61.53º, 65.79º, 66.25º, 72.43º, and 75.03º. Crystalline size 14 nm.	
6.	H. Raja Naika *et. al*	2015	CuO NP using *Gloriosasuperba*	SEM	Spherical	37
				TEM	Spherical, size- 5-10 nm	
				XRD	Crystalline size 8 nm	
7.	Lily Riya and Mary George	2015	CuO NP using *Camellia sinensis*	FT-IR	Peaks at 622 cm^{-1}	38
				XRD	2Ө values 29.50º, 36.38º, 42.29º, 52.47º, 61.43º, 73.62º and 77.50º.	
8.	MarymBordbar *et. al*	2016	CuO NP using *Rheum palmatum*	SEM	Spherical, size- 30nm.	39
				TEM	Spherical, size-10-20 nm.	
				FT-IR	Peaks at 400-600 cm^{-1}.	
				XRD	2Ө values 35.39º, 38.77º, 48.85º and 61.69º.	
9.	ILL-MIN Chung *et. al*	2016	CuO NP using *Ecliptaprostrata*	SEM	Spherical, hexagonal and cubical. Size- 28-105 nm.	40
				TEM	Spherical, size- 28-45 nm.	
				FT-IR	Peaks at 3333, 2917, 1615, 1048 cm^{-1}.	
				XRD	2Ө values 31.65º, 45.42º, 66.14º and 75.14º.	
10.	Long-Bao Shi *et. al*	2017	CuO NP using *Cassia auriculata*	SEM	Spherical shape	41
				TEM	Spherical, size- 23.70 nm	
				FT-IR	Peaks at 3385, 2922, 1720, 1612, 1033, 668 and 601 cm^{-1}.	
				XRD	2Ө values 32.54º, 35.56º, 38.77º, 48.74º, 53.53º, 58.37º, 61.56º, 66.29º and 68.17º.	
11.	Mangesh S. Jadhav *et. al*	2017	CuO NP using *Malus Domestica*	SEM	Spherical, size- 18-20 nm.	42
				TEM	Size- 18-20 nm.	
				FT-IR	Peak values 3448.20, 2966.80, 2924.59, 2854.40, 1751.10, 1630.97, 1465.58, 1402.41, 1265.41, 1028.17 and 711.18 cm^{-1}.	
				XRD	2Ө values 23.501º and 42.695º.	

Literature clearly shows the characterization of CuO NPs by using different methods. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) confirms the size and shape of nanoparticles. Size of nanoparticles between 1-100nm is considered for excellent catalytic activity. Fourier-transform infrared spectroscopy (FT-IR) is utilized for the structural confirmation of molecules present inside the prepared sample. FT-IR gives the information about bond stretching in particular sample. CuO NPs shows bond stretching between 2800 -4000 cm^{-1}. X-ray Diffraction (XRD) method is used to know the crystalline structure of CuO nanoparticles. Metallic nature of CuO nanoparticles gives the $2\Theta = 42^{\circ}$ to 48°. Current review highlights the detailed characterization and synthetic methods for CuO nanoparticles which can be helpful to understand and predict the properties of CuO NPs.

CONCLUSION

The review highlights the green chemistry approach for the synthesis of CuO nanoparticles is simple, cost effective and eco-friendly. The resultant NPs are highly stable and reproducible. Simple, eco- friendly green synthesis of CuO NPs has been reported using different leaf extract as capping and reducing agent. Here, green extract was used for the reduction of copper material at Nano scale. The present study establishes that rod or spherical shape NPs of CuO can be obtained by using these method. The characterization of CuO NPs is done by using various analytic instrument like SEM, TEM, FT-IR and XRD, which are helpful for further analysis these prepared CuO NPs has used for various applications for better human life such as it can be implemented in anti-cancer, anti-microbial, anti-oxidant activity etc.

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