International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

Synthesis and Characterization of Carbon Nanoparticles using Calotropis procera Extract

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Abstract:
Calotropis procera is considered a medicinal plant belonging to the Asclepiadaceae family, surrounded throughout India and in other tropical areas. The common names of C. procera are Arka, Akanal, Madar, and Akanda. Based on the morphological characteristics, the leaves of C. procera is characterized as ovate, obovate, ovate-oblong or elliptical. This study explores the synthesis of Carbon nanoparticles (CNPs) which have emerged as promising materials for various applications due to their unique properties, including high surface area, excellent electrical conductivity, and biocompatibility. In this research, we present a novel method for the synthesis of CNPs utilizing Calotropis procera, a widely available and renewable plant source. The synthesis process involves the pyrolysis of Calotropis procera biomass under controlled conditions, followed by subsequent purification steps to obtain pure CNPs. The synthesized CNPs were characterized using techniques such as scanning electron microscopy (SEM) and X-ray diffraction (XRD) to determine their morphology, crystalline structure, and functional groups. The utilization of Calotropis procera as a precursor for CNP synthesis offers a sustainable and eco-friendly approach, contributing to the development of green nanotechnology. The abundance and accessibility of Calotropis procera make this method cost-effective and scalable, paving the way for large-scale production of CNPs with minimal environmental impact.

Keywords: Nanoparticles, XRD, SEM, Synthesis, Morphology, and Pyrolysis

1. Introduction to Calotropis procera:

Calotropis procera is a resilient and long-lived perennial shrub classified under the family Apocynaceae, a family previously regarded as Asclepiadaceae due to similarities in flower structure and latex-producing abilities. It is predominantly distributed across the arid and semi-arid regions of Africa, the Indian subcontinent, and parts of the Middle East. Typically, the plant grows to heights ranging from 1.8 to 4.5 meters and is well adapted to poor soils and intense sunlight, characteristics that contribute to its

success as a pioneer species in xeric landscapes [1]. The leaves are positioned oppositely on thick, upright stems and are covered in a greyish, waxy cuticle that minimizes water loss. The plant's reproductive structures include unique five-lobed flowers, often purplish, arranged in loose umbels. A prominent feature of Calotropis procera is the production of copious amounts of white latex, a milky exudate containing cardiac glycosides and cysteine proteases which are essential for the plant's natural defense mechanisms and also underlie many of its medicinal properties [2].

Detailed anatomical investigations confirm that the leaves display a complex mesophyll comprising multiple layers of palisade cells and large intercellular spaces filled with spongy parenchyma. The upper epidermis is heavily cuticularized, serving as an efficient barrier against transpiration. Additionally, lactiferous canals distributed within the pericarp tissues further support the plant's classification as a xerophyte, with special adaptations that reduce water loss and increase resilience in drought-prone environments [3]. The species demonstrates significant Morpho-anatomical plasticity. For instance, under conditions of high salinity or limited water availability, Calotropis procera modifies its leaf thickness, increases or decreases stomatal density, and reinforces its tissues to exhibit sclerophylly, all of which contribute to enhanced drought tolerance and survivability across a range of climates [4]. The taxonomic placement of Calotropis procera can be described as follows: it belongs to the Kingdom Plantae, which encompasses all green plants; the Order Gentianales, known for species with milky sap and opposite leaves; the Family Apocynaceae, which includes latex-producing plants with complex floral structures; the Subfamily Asclepiadoideae, characterized by specialized floral morphologies adapted for pollination; the Genus Calotropis; and the Species procera. [5].

2. Significance of Nanoparticles and Calotropis-Based Nanoparticles:

Nanoparticles (NPs), especially those synthesized through green methods, have gained immense attention due to their biocompatibility, eco-friendliness, and multifunctional applications across biomedical, agricultural, and environmental fields. NPs exhibit a high surface area-to-volume ratio, unique optical and electronic properties, and tunable surface chemistry, making them suitable for drug delivery, bio-sensing, water purification, and antimicrobial applications [6]. Specifically, silver nanoparticles (AgNPs) synthesized from biological agents such as plants show enhanced antimicrobial activity due to their ability to disrupt microbial membranes and generate reactive oxygen species [7]. In one study, AgNPs synthesized using Calotropis procera leaf extract displayed significant antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa, with particle sizes between 20-30 nm confirmed through TEM and XRD analysis [8]. Another investigation reported that Calotropis-mediated zinc oxide nanoparticles (ZnO NPs) exhibited improved antioxidant activity and enzyme inhibition (urease, acetylcholinesterase) compared to the plant extract alone [9]. Furthermore, copper nanoparticles (CuNPs) synthesized from C. procera latex exhibited cytotoxicity toward cancer cell lines (A549 and HeLa) while maintaining compatibility with non-cancerous BHK-21 cells, suggesting potential for targeted drug delivery systems [10]. The synthesis process from Calotropis not only reduces metal ions but also caps and stabilizes the nanoparticles using phytochemicals like flavonoids, terpenoids, and saponins present in the extract. This dual role enhances their stability and biological activity, positioning Calotropis-derived nanoparticles as promising candidates for therapeutic and environmental applications.

Methodology: Green Synthesis of Nanoparticles Using Calotropis procera:

The green synthesis of nanoparticles using Calotropis procera is an emerging and environmentally benign technique that harnesses the plant's bioactive compounds to reduce metal ions into stable nanoparticles. The process typically begins with the careful selection and preparation of plant material. The fresh or shade-dried leaves are collected, thoroughly washed with deionized water or mild detergents (like sodium lauryl sulphate) to remove dust and microbes, and then dried under shade to preserve thermolabile phytochemicals [11].

About 10 to 50 g of the plant material is boiled in 100ml of deionized water for 15 to 30 minutes. This aqueous extraction process helps release bioactive components such as flavonoids, alkaloids, tannins, terpenoids, saponins, and phenolic compounds into solution, which later serve as reducing and stabilizing agents in nanoparticle synthesis [12]. After boiling, the extract is cooled and filtered using Whatman No.1 filter paper or muslin cloth to remove any particulate matter. This extract is either used immediately or stored in a refrigerator to retain its reducing potential [13].

The synthesis of nanoparticles is initiated by mixing the prepared plant extract with 1mM Na_2CO_3 in the ratio 1:10 (extract: metal solution). The reaction mixture is stirred magnetically at room temperature for 30 minutes. A colour change is observed from pale yellow to reddish brown formation [14].

After the reaction, the solution is centrifuged at 8,000 to 12,000 rpm for 15-20 minutes to separate the nanoparticles. The mixture was kept for drying in a hot air oven at 50-60 °C for 12-24 hours to obtain dry nanoparticle powder. Some studies also employed calcination (typically at 400 °C) to enhance crystallinity and remove any organic residues when synthesizing metal oxide nanoparticles like ZnO or Fe_3O_4 [15].

Characterization of the synthesized nanoparticles includes a variety of techniques. **Scanning Electron Microscopy (SEM)** provides morphological analysis and particle size distribution. Studies reported spherical to irregular particles in the range of 15 to 80 nm, depending on precursor salt, temperature, and duration of reaction. **X-ray Diffraction (XRD)** analysis confirms the crystalline structure, with prominent peaks corresponding to fcc (face-centred cubic) lattice of silver, hexagonal phase of ZnO, or cubic magnetite for Fe_3O_4 NPs [16].

3. Results And Discussion:

SEM IMAGES:

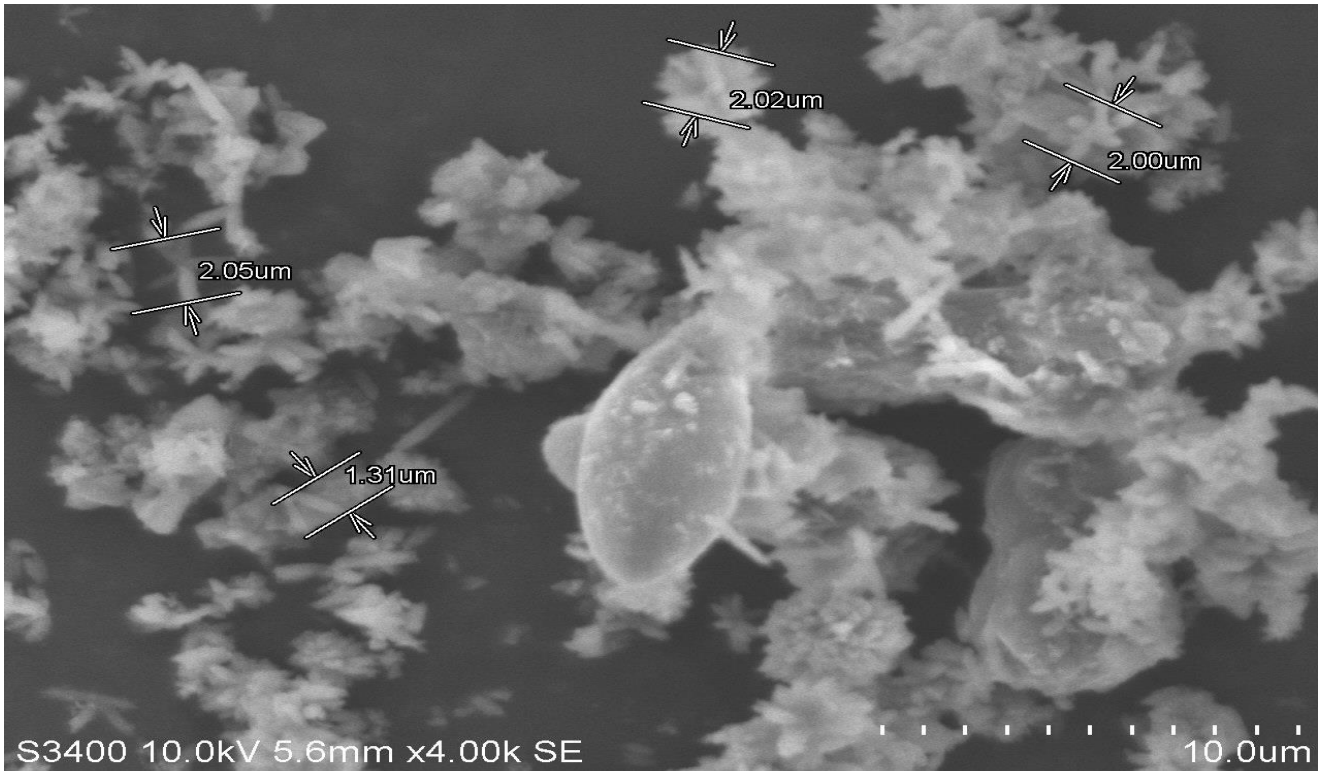

Figure 1: SEM image of C- NPs revealing the different size of nanoparticles such as 2.05µm, 2.02µm, 2.0µm and 1.31µm

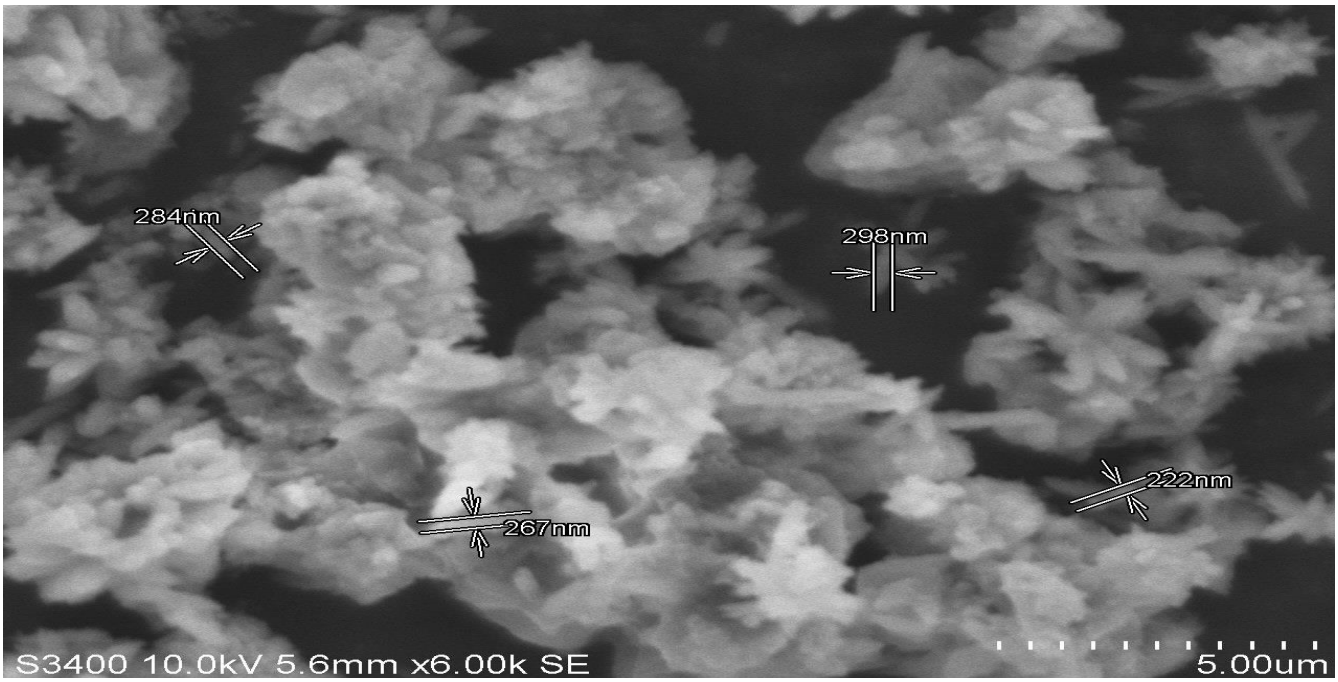

Figure 2: SEM image of Carbon nanotube structures possessing 284µm, 298µm, 222µm and 267µm SEM examination further revealed predominantly well-defined shape of C-NPs.

XRD ANALYSIS DATA

Table 1: Data obtained from XRD Analysis

Intensity (cps)	Characteristic	Value	ESD Value
3700	2-theta(degree)	17.3293	0.0025
	D(angle)	5.11313	0.00073
	Height(counts)	463.33	21.5252
	FWHM (degree)	0.0396	0.0028
	Int. I(degree)	22.9	0.78829
	Int. W(degree)	0.0494	0.004
	Asymmetric factor	1.9042	0.67643
	eta L/mL	0.4362	0.1559
	eta H/mH	0.4921	0.32649
	Size(ang.)	2118.6	149.798
	Rel. int. I	80.44	-
	Rel. height	100	-
	Peak shape	Split pseudo-Voigt	-
4200	2-theta(degree)	31.9553	0.03163
	D(angle)	2.79841	0.00269
	Height(counts)	64.2	8.012
	FWHM (degree)	0.382	0.0267
	Int. I(degree)	28.47	2.04147
	Int. W(degree)	0.4435	0.08715
	Asymmetric factor	1.812	0.61208
	eta L/mL	0.1189	0.3183
	eta H/mH	0.4797	0.40599
	Size(ang.)	225.94	15.5396
	Rel. int. I	100	-
	Rel. height	13.86	-
	Peak shape	Split pseudo-Voigt	-

1

XRD Spectra

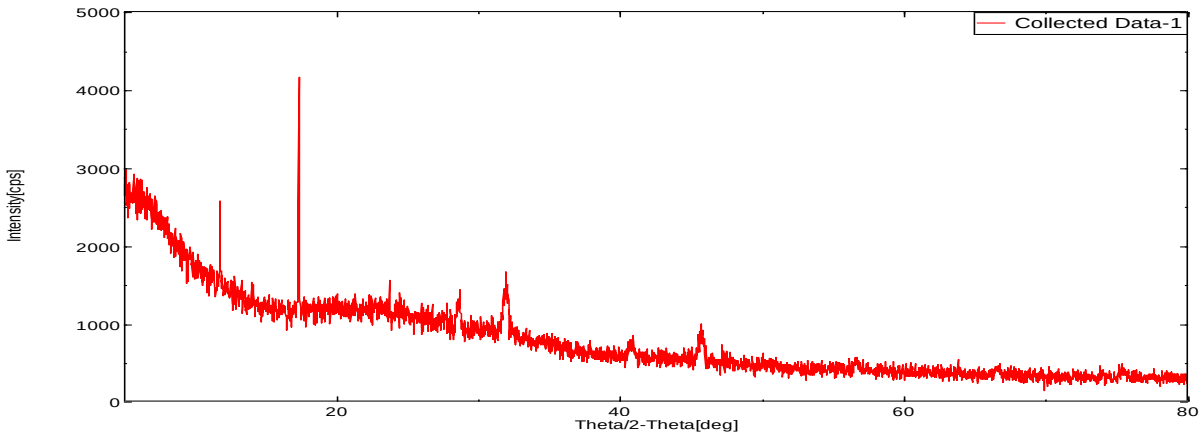

Figure 3: XRD spectra of Carbon sample. XRD analysis successfully demonstrated the nature of C-NPs. The peak positions were consistent. This method was based on projecting a monochromatic X-ray beam onto the material at theta (θ) angle. The Full Width at Half Maximum (FWHM) was measured for planes of reflection (290,291) and. The strong and sharp peaks revealed crystalline nature of C-NPs. Additionally, some undesired peaks were also noticed, suggesting the crystalline organic phase of C-NPs.

4. Conclusion

In this study, we report the synthesis of the carbon nanoparticles using the plant extract of Calotropis procera, which is the primary objective. It suggests an inexpensive, environment friendly and very effective method of synthesizing carbon nanoparticles. Calotropis procera leaf extract was used for the synthesis of C-NPs. By mixing Calotropis procera plant extract with Na_2CO_3 solution, a colour shift was detected, indicating an actual reduction process. Characterization techniques such as Scanning electron microscope (SEM) revealed a well-defined shape of C-NPs. The strong and sharp peaks in X-ray diffraction spectroscopy (XRD) revealed the crystalline nature of C-NPs. Additionally, some undesired peaks were also noticed, suggesting the crystalline organic phase of C-NPs justifies the formation of carbon nanoparticles.

5. Acknowledgement

We would like to express our sincere gratitude to the Management and Principal, Sapthagiri College of Engineering, Bengaluru for the facilities provided and their support. Also, we would like to thank the Head of the Department of Biotechnology and the faculty for their encouragement and support.

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