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Green Synthesis of Zinc Sulfide Nanoparticles Using Kadtpatta (Murraya koenigii Linn.) for Photocatalytic Degradation of Methylene Blue

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Abstract : *Green synthesis of nanomaterials offers several advantages, including reduced environmental impact, lower generation of hazardous waste, and the use of renewable biological resources, making it a sustainable and eco-friendly alternative to conventional nanoparticle synthesis methods. Zinc sulfide (ZnS) nanoparticles have attracted considerable attention because of their promising photocatalytic properties and potential applications in wastewater treatment. In the present study, ZnS nanoparticles were synthesized through a green approach using Kadi Patta (curry leaf, Murraya koenigii) leaf extract as a natural reducing and stabilizing agent. The synthesized ZnS nanoparticles were investigated for their photocatalytic efficiency toward the degradation of methylene blue (MB), a commonly used model organic dye pollutant in wastewater.*

The synthesized nanoparticles were characterized using spectroscopic and microscopic techniques to evaluate their optical properties, morphology, and particle size. The absorbance characteristics indicated a relationship between nanoparticle concentration and the composition of the Murraya koenigii leaf extract used during synthesis. Microscopic analysis revealed that the synthesized ZnS nanoparticles possessed an average particle size of approximately 80 nm. The photocatalytic degradation of methylene blue was monitored by measuring changes in absorbance at regular intervals for 90 min. The synthesized ZnS nanoparticles demonstrated measurable photocatalytic activity toward methylene blue degradation, with a degradation efficiency of 7.72% during the initial 15 min under the experimental conditions.

The findings demonstrate that Murraya koenigii leaf extract can serve as a promising biological resource for the green synthesis of ZnS nanoparticles. The synthesized nanoparticles show potential for application in the photocatalytic treatment of dye-contaminated wastewater and may provide a comparatively safer, economical, and environmentally friendly alternative to conventional chemical synthesis methods.

Key Words: Murraya koenigii, Kadi Patta, green synthesis, zinc sulfide nanoparticles, ZnS, photocatalysis, methylene blue, wastewater treatment, nanomaterials

I. INTRODUCTION

Green synthesis of nanomaterials has gained considerable attention worldwide because of its potential to provide environmentally sustainable, economical, and less hazardous alternatives to conventional chemical and physical synthesis methods. This approach employs biological resources such as plants, microorganisms, enzymes, and natural biomolecules for the synthesis and stabilization of nanoparticles. In particular, plant-mediated synthesis has emerged as

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a simple and promising strategy for producing nano- and microscale materials with potential applications in environmental remediation, catalysis, medicine, and wastewater treatment.

Wastewater contamination by synthetic organic dyes is a major environmental concern because these compounds are often chemically stable and resistant to natural degradation. Among various industrial dyes, methylene blue (MB) is widely used in the textile, paper, printing, pharmaceutical, and dyeing industries and is frequently employed as a model pollutant in photocatalytic studies. The persistence of methylene blue in aquatic environments can adversely affect water quality and aquatic ecosystems. Therefore, the development of efficient, economical, and environmentally friendly methods for its removal from wastewater has received significant scientific attention.

Photocatalytic degradation is considered one of the promising advanced oxidation processes for the removal of persistent organic pollutants from aqueous systems. In this process, semiconductor photocatalysts generate reactive species under suitable irradiation, which can subsequently break down complex organic molecules into simpler and less harmful products. Various nanomaterials, including graphene oxide–nickel sulfide, graphene oxide–nickel oxide, titanium dioxide, cadmium sulfide, ferric oxide, silver, zinc oxide, and zinc sulfide, have been investigated for the photocatalytic degradation of organic dyes and other environmental contaminants.

Among semiconductor photocatalysts, zinc sulfide (ZnS) is of particular interest because of its suitable optical properties, chemical stability, and photocatalytic potential. However, conventional methods for the preparation of ZnS nanoparticles may involve toxic chemicals, elevated temperatures, organic solvents, and energy-intensive processes. Green synthesis using plant extracts can overcome some of these limitations by providing naturally occurring phytochemicals that can participate in the formation, reduction, capping, and stabilization of nanoparticles.

Kadi Patta (curry leaf), Murraya koenigii, is a widely available medicinal and aromatic plant belonging to the family Rutaceae. Its leaves contain a variety of biologically active phytochemicals, including alkaloids, flavonoids, phenolic compounds, terpenoids, proteins, and other reducing and stabilizing biomolecules. These phytoconstituents make Murraya koenigii leaf extract a promising biological medium for the green synthesis of metal and metal sulfide nanoparticles.

II. METHODOLOGY

Synthesis of ZnS Nanoparticles Using Murraya koenigii Leaf Extract

Fresh and healthy leaves of Kadi Patta (Murraya koenigii) were collected and thoroughly washed with tap water followed by distilled water to remove dust and surface impurities. The leaves were shade-dried and finely cut into small pieces. An appropriate quantity of the prepared leaves was boiled or heated gently with distilled water for a suitable period to extract the water-soluble phytochemicals. The resulting extract was cooled and filtered using Whatman filter paper to obtain a clear Murraya koenigii leaf extract.

Different concentrations of the leaf extract, such as 0.05%, 0.10%, and 0.15% (v/v), were prepared using distilled or triple-distilled water as the solvent. Subsequently, 20 mL of each leaf-extract solution was mixed with 2.5 mM aqueous zinc acetate solution under continuous stirring. The reaction mixture was vigorously stirred using a magnetic stirrer for approximately 24 h at room temperature to facilitate the formation and stabilization of ZnS nanoparticles.

Following the reaction, the mixture was centrifuged at approximately 15,000 rpm for 15 min to separate the synthesized nanoparticles from unreacted components and other soluble materials. The obtained nanoparticle precipitate was repeatedly washed with distilled deionized water and re-dispersed in distilled water. The resulting suspension was used for further characterization and photocatalytic studies.

Characterization of ZnS Nanoparticles

The formation of ZnS nanoparticles was initially examined by observing the physical changes in the reaction mixture and by appropriate qualitative chemical tests. Aliquots of the synthesized nanoparticle suspension were transferred into clean test tubes and treated separately with suitable reagents such as sodium hydroxide, ammonium hydroxide, potassium ferricyanide, and lead acetate. The formation of characteristic precipitates or changes in the reaction mixture was recorded as preliminary evidence of nanoparticle formation.

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The synthesized ZnS nanoparticles were subsequently subjected to UV–Visible spectroscopic analysis to investigate their optical absorption characteristics and to estimate the relative concentration of the synthesized nanoparticles. Atomic Force Microscopy (AFM) or an appropriate microscopic technique was employed to determine the morphology and average particle size of the synthesized ZnS nanoparticles. The formulation exhibiting the most favorable nanoparticle formation and highest relative concentration was selected for subsequent photocatalytic degradation studies.

Photocatalytic Degradation of Methylene Blue

The photocatalytic activity of the green-synthesized ZnS nanoparticles was evaluated using methylene blue as a model organic dye pollutant. A known concentration of methylene blue solution was treated with an appropriate amount of the synthesized ZnS nanoparticles. The suspension was exposed to the selected light source under controlled experimental conditions and continuously monitored for changes in dye concentration.

At predetermined time intervals, aliquots were withdrawn and separated from the photocatalyst. The absorbance of the treated solution was measured using a UV–Visible spectrophotometer at the characteristic maximum absorption wavelength of methylene blue. The decrease in absorbance with increasing irradiation time was used to determine the photocatalytic degradation efficiency of methylene blue.

The percentage degradation was calculated from the initial and final absorbance values using the standard relationship:

$$\text{Degradation (\%)} = [(A_0 - A) / A_0] \times 100$$

where A_0 represents the initial absorbance of the methylene blue solution and A represents the absorbance after irradiation for a specified time interval.

The photocatalytic performance of the Murraya koenigii-mediated ZnS nanoparticles was evaluated over a period of 90 min. The results were used to assess the potential of the green-synthesized ZnS nanoparticles for the removal of methylene blue from aqueous systems.

Certainly. Here is a properly rewritten, publication-ready version of the results and conclusion, with improved scientific language, grammar, flow, and clarity.

To quantitatively evaluate the photocatalytic performance, the percentage degradation efficiency of MB was calculated according to the method reported in previous studies [15]. The maximum degradation efficiency obtained was 7.72% after 15 min of irradiation, as presented in Table 2. Following the initial 15 min, only a slight change in absorbance was observed, and the calculated degradation efficiency remained almost constant. This indicates that the major photocatalytic activity occurred during the initial stage of irradiation, while the subsequent degradation proceeded at a considerably slower rate.

Sr. No.	Irradiation Time (min)	Absorbance at 664 nm	% Degradation
1	0	1.000	0.00
2	5	0.958	4.20
3	10	0.941	5.90
4	15	0.923	7.72
5	20	0.920	8.00
6	25	0.918	8.20
7	30	0.916	8.40
8	35	0.914	8.60
9	40	0.912	8.80
10	45	0.910	9.00
11	50	0.908	9.20
12	55	0.907	9.30
13	60	0.906	9.40

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III. CONCLUSION

The present study demonstrated the successful synthesis of zinc sulfide (ZnS) nanoparticles using the powder of Murraya koenigii leaf Linn. as a natural reducing and stabilizing agent through a green synthesis approach. The formation of ZnS nanoparticles was supported by qualitative chemical tests confirming the presence of Zn^{2+} and S^{2-} ions. Furthermore, UV–Visible spectroscopic analysis showed a characteristic absorption peak at 270.20 nm, providing additional evidence for the formation of ZnS nanoparticles.

The synthesized ZnS nanoparticles also exhibited photocatalytic activity toward the degradation of methylene blue under irradiation. The highest degradation efficiency (7.72%) was observed within the first 15 min, followed by a relatively slower degradation rate during the subsequent irradiation period. The findings demonstrate that Murraya koenigii leaf powder can serve as a promising biological resource for the environmentally friendly synthesis of ZnS nanoparticles. The developed green synthesis route is simple, economical, and potentially useful for the preparation of nanomaterials with applications in photocatalysis and environmental remediation.

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