International Organization of Research & Development (IORD)
ISSN: 2348-0831
Vol 13 Special Issue 02 | 2026

Application of Calotropis PROCERA in Water Treatment Processes: A Comparative Review

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DOI: 10.5281/zenodo.19538704

ABSTRACT

Water pollution caused by industrialization, urbanization, and agricultural activities has resulted in the presence of turbidity, dyes, heavy metals, and organic contaminants in water resources. Conventional treatment methods involving chemical coagulants and synthetic adsorbents are often expensive and may generate secondary pollution. Recently, plant-based materials have emerged as sustainable alternatives due to their eco-friendly nature, biodegradability, and low cost. Calotropis procera, a xerophytic plant widely available in tropical and subtropical regions, contains natural polymers, proteins, and functional groups capable of interacting with contaminants. This review presents a comprehensive analysis of the application of Calotropis procera in water and wastewater treatment processes including coagulation–flocculation, adsorption, photocatalytic degradation, and phytoremediation. Comparative statistical analysis, mechanisms of pollutant removal, operational parameters, advantages, limitations, and future research directions are discussed. The findings indicate that Calotropis procera is a promising sustainable material for water purification, particularly in developing countries.

Keywords:- Calotropis procera, natural coagulant, biosorption, heavy metals, phytoremediation, wastewater treatment

1. INTRODUCTION

Water is an essential natural resource required for human survival, agriculture, and industrial activities. However, rapid industrial growth and population increase have resulted in severe contamination of water bodies with suspended particles, dyes, heavy metals, and organic pollutants. Heavy metals such as cadmium, chromium, lead, and nickel are particularly hazardous due to their toxicity, persistence, and bioaccumulation potential.

Conventional water treatment technologies such as chemical coagulation, ion exchange, and membrane filtration are effective but often involve high operational costs and environmental concerns related to sludge disposal. Therefore, the search for low-cost and eco-friendly treatment materials has gained significant attention. Plant-based materials have emerged as promising alternatives due to their abundance, biodegradability, and adsorption capacity. Among these, Calotropis procera has attracted interest due to its unique chemical composition and environmental tolerance. Various studies have demonstrated its potential in turbidity removal, heavy metal adsorption, dye degradation, and phytoremediation applications.

1.1 Botanical and Chemical Characteristics of Calotropis procera

Calotropis procera is a perennial shrub belonging to the Apocynaceae family, commonly found in arid and semi-arid regions. The plant contains latex, leaves, roots, and biomass rich in bioactive compounds including:

Proteins and enzymes, Polysaccharides, Alkaloids and flavonoids, Functional groups (hydroxyl, carboxyl, amine)

These components contribute to coagulation, adsorption, and metal-binding properties, making the plant suitable for water treatment applications.

2. APPLICATIONS IN WATER TREATMENT

2.1 Coagulation–Flocculation for Turbidity Removal Coagulation–flocculation is widely used to remove suspended particles from water. Chemical coagulants such as alum are effective but may cause health concerns and sludge disposal issues.

Plant extracts from Calotropis procera contain cationic proteins that neutralize negatively charged particles in water, resulting in floc formation and sedimentation. Studies have reported turbidity removal efficiencies between 70% and 90% under optimized conditions.

Danlami et al. (2014) demonstrated significant turbidity reduction using leaf extract of Calotropis procera, confirming its potential as a natural coagulant.

2.2 Adsorption of Heavy Metals.

Adsorption is considered one of the most effective methods for removing heavy metals from wastewater. Biomass derived from Calotropis procera acts as a biosorbent due to the presence of functional groups capable of binding metal ions.

Hosamane et al. (2022) reported cadmium removal efficiencies up to 95% using optimized experimental conditions. The adsorption mechanism involves:

Ion exchange, Surface complexation, Electrostatic attraction, Chemisorption

These mechanisms contribute to high removal efficiency and make the plant suitable for heavy metal remediation.

2.3 Dye Removal and Photocatalytic Applications

Textile industries release dye-contaminated wastewater that is difficult to treat using conventional methods.

Recent research has explored green synthesis approaches using plant extracts to enhance photocatalytic degradation.

Modification of TiO_2 catalysts using Calotropis procera extract improves photocatalytic activity and dye degradation efficiency (~90%). The improvement is attributed to increased surface area and enhanced generation of reactive oxygen species.

This approach combines nanotechnology with green chemistry for sustainable water treatment.

2.4 Phytoremediation Potential

Phytoremediation involves the use of plants to remove contaminants from soil and water through absorption, accumulation, and detoxification processes.

Studies have shown that Calotropis procera can tolerate and accumulate heavy metals such as chromium, nickel, and lead. Environmental studies confirmed significant metal uptake and accumulation capacity, demonstrating its potential for remediation of contaminated environments.

3. MECHANISMS OF POLLUTANT REMOVAL

The removal of contaminants using Calotropis procera occurs through multiple mechanisms depending on the treatment process:

1. Charge neutralization during coagulation
2. Adsorption via functional groups
3. Ion exchange with metal ions
4. Complex formation with organic pollutants
5. Photocatalytic oxidation through reactive oxygen species
6. Phytoaccumulation in plant tissues

These mechanisms contribute collectively to efficient pollutant removal.

3.1 Factors affecting treatment efficiency

Several operational parameters influence removal efficiency:

pH

pH significantly affects adsorption and coagulation performance. Maximum removal is generally observed near neutral pH due to reduced proton competition and favorable surface charge conditions.

3.2 Adsorbent Dosage

Increasing biomass dosage increases removal efficiency due to availability of more binding sites until saturation occurs.

- Contact Time: Removal efficiency increases with contact time until equilibrium is reached.
- Initial Pollutant Concentration: Higher concentrations may reduce efficiency due to limited adsorption sites.

Comparative Statistical Analysis

Based on literature studies:

Application	Removal Efficiency Range
Coagulation	70-90%
Adsorption	80-95%
Photocatalysis	85-92%
Phytoremediarion	Moderate to High

Adsorption shows the highest efficiency due to strong chemical interaction between biomass and pollutants.

3.3 Advantages of Using Calotropis procera

Abundant and low-cost material, Biodegradable and eco-friendly, Reduced chemical sludge generation, Multi-functional applications, Suitable for rural and developing regions, Renewable

3.4 Limitations

Despite promising results, several challenges remain:
Limited large-scale application studies, Variation in plant composition, Storage stability issues, Need for process optimization, Lack of commercial production

3.5 Future Research Directions

Future research should focus on:
Chemical modification of biomass for improved adsorption, Integration with nanotechnology, Development of hybrid treatment systems, Pilot-scale implementation, Life cycle and cost analysis, Sludge reuse and management

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4. CONCLUSIONS

Calotropis procera has demonstrated significant potential as a sustainable material for water treatment applications including coagulation, adsorption, photocatalysis, and phytoremediation. Comparative analysis shows removal efficiencies comparable to conventional treatment methods under optimized conditions. Due to its low cost, availability, and environmental compatibility, the plant offers a promising alternative for water purification, particularly in developing countries. Further research and large-scale implementation studies are required to fully utilize its potential in modern water treatment technologies.

5.ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my project guide for their valuable guidance, continuous support, and encouragement throughout the completion of this review work on Calotropis procera in water treatment processes. Their expert advice and constructive suggestions greatly helped in improving the quality of this study.
I am also thankful to the faculty members of the Civil/Environmental Engineering Department for providing the necessary academic knowledge, resources, and motivation required for the successful completion of this work.
I would like to acknowledge the authors and researchers whose published studies and scientific contributions formed the foundation of this review paper. Their research provided important insights into the applications of Calotropis procera in sustainable water treatment technologies.
Finally, I express my heartfelt gratitude to my parents, friends, and well-wishers for their constant encouragement, moral support, and motivation during the preparation of this report.

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