



**KALASALINGAM**  
**ACADEMY OF RESEARCH AND EDUCATION**  
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## Research Proposal

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# Green Chemistry Approaches for Sustainable Nanoparticle Synthesis from Recycled Batteries

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## 1. Introduction

The global demand for batteries, especially lithium-ion and alkaline types, has increased rapidly due to their applications in consumer electronics, renewable energy storage, and electric vehicles. However, the disposal of used batteries poses a significant environmental threat, as they contain toxic heavy metals (e.g., Cd, Pb, Ni) and valuable transition metals (e.g., Mn, Co, Li, Zn). Traditional recycling methods often rely on energy-intensive or hazardous processes, contradicting sustainability goals.

Green chemistry provides an eco-friendly framework for recycling these batteries, enabling the recovery of valuable metals without harmful by-products. These recovered metals can be used for the green synthesis of nanoparticles (NPs), using plant extracts, microorganisms, or biopolymers as natural reducing and stabilizing agents. Such nanoparticles exhibit unique properties—high surface area, catalytic activity, and tunable size—making them promising for applications in catalysis, energy storage, and environmental remediation.

This project aims to integrate battery recycling with green nanoparticle synthesis, thereby addressing waste management, promoting a circular economy, and advancing sustainable nanotechnology.

## 2. Research Problem

Conventional methods for nanoparticle synthesis often involve toxic chemicals, high energy input, and generate hazardous waste. Simultaneously, discarded batteries pose a serious environmental risk due to the leaching of heavy metals. There is a critical need for:

- Sustainable methods to recycle and repurpose waste batteries.
- Environmentally benign synthesis routes for functional nanoparticles.
- Development of scalable green chemistry approaches that combine waste valorization and nanotechnology.

### 3. Objectives

- To recover valuable metals (e.g., Li, Co, Ni, Mn) from spent batteries.
- To synthesize nanoparticles using green chemistry methods (biogenic reduction, plant extracts, solvent-free processes, etc.).
- To characterize the structural, morphological, and functional properties of the synthesized nanoparticles.
- To evaluate potential applications of these nanoparticles (e.g., catalysis, energy storage, water treatment, sensors).
- To assess the sustainability and environmental impact of the proposed method compared to conventional synthesis.

### 4. Methodology

#### 4.1 Recovery of Metals from Batteries

- Collection and dismantling of spent batteries.
- Pre-treatment: crushing, separation of cathode/anode materials.
- Green leaching: organic acids (citric/oxalic acid) instead of strong mineral acids.
- Filtration and purification of extracted metal ions ( $\text{Mn}^{2+}$ ,  $\text{Co}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Zn}^{2+}$ ).

#### 4.2 Green Synthesis of Nanoparticles

- Plant extracts (e.g., tea, neem, aloe vera) as reducing agents.
- Biopolymers (starch, chitosan) for stabilization.
- Control of synthesis parameters: pH, temperature, and time.

#### 4.3 Characterization Techniques

- XRD (X-ray Diffraction): To determine crystal structure and phase purity.
- SEM/TEM (Scanning & Transmission Electron Microscopy): To study morphology, particle size, and distribution.

- FTIR (Fourier Transform Infrared) Spectroscopy: To identify functional groups and bonding.
- UV-Vis Spectroscopy: To analyze optical properties and bandgap estimation.
- Zeta Potential Analysis: To evaluate surface charge and colloidal stability.
- Raman Spectroscopy: To investigate vibrational modes, bonding characteristics, and defects.
- XPS (X-ray Photoelectron Spectroscopy): To determine surface composition, oxidation states, and electronic environment.
- Electrochemical Studies (CV, EIS, GCD): To evaluate electrochemical performance for energy storage and catalytic applications.
- DFT (Density Functional Theory) Calculations: To provide theoretical insights into electronic structure, reaction mechanisms, and stability of the synthesized nanoparticles.

#### 4.4 Applications

- Catalysis: degradation of organic dyes (methylene blue).
- Energy storage: electrodes for supercapacitors/batteries.
- Antimicrobial activity: bacterial growth inhibition tests.

#### 5. Expected Outcomes

- A sustainable, low-cost method for recycling metals from batteries.
- Successful synthesis of nanoparticles using green chemistry.
- Correlation of synthesis method with particle size, stability, and properties.
- Demonstrated potential in environmental and energy applications.

#### 6. Significance of Study

- Supports circular economy by transforming hazardous waste into value-added nanomaterials.
- Reduces dependency on mining, minimizing environmental impact.

- Provides a green alternative to chemical and physical synthesis methods.
- Potential for industrial applications in energy, environment, and healthcare.

## 7. References

1. Anastas, Paul T, and John C Warner, *Green Chemistry: Theory and Practice* (Oxford, 2000; online edn, Oxford Academic, 31 Oct. 2023), <https://doi.org/10.1093/oso/9780198506980.001.0001>, accessed 9 Sept. 2025.
2. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green chemistry*, 13(10), 2638-2650. <https://doi.org/10.1039/C1GC15386B>
3. Fan, B., Chen, X., Zhou, T., Zhang, J., & Xu, B. (2016). A sustainable process for the recovery of valuable metals from spent lithium-ion batteries. *Waste Management & Research*, 34(5), 474-481. <https://doi.org/10.1177/0734242X16634454>
4. Nie, Y., Zhou, Y., Zhang, Y., Sun, D., Wu, D., Ban, L., ... & Zhang, H. (2025). Sustainable synthesis of functional materials assisted by deep eutectic solvents for biomedical, environmental, and energy applications. *Advanced Functional Materials*, 35(19), 2418957. <https://doi.org/10.1002/adfm.202418957>